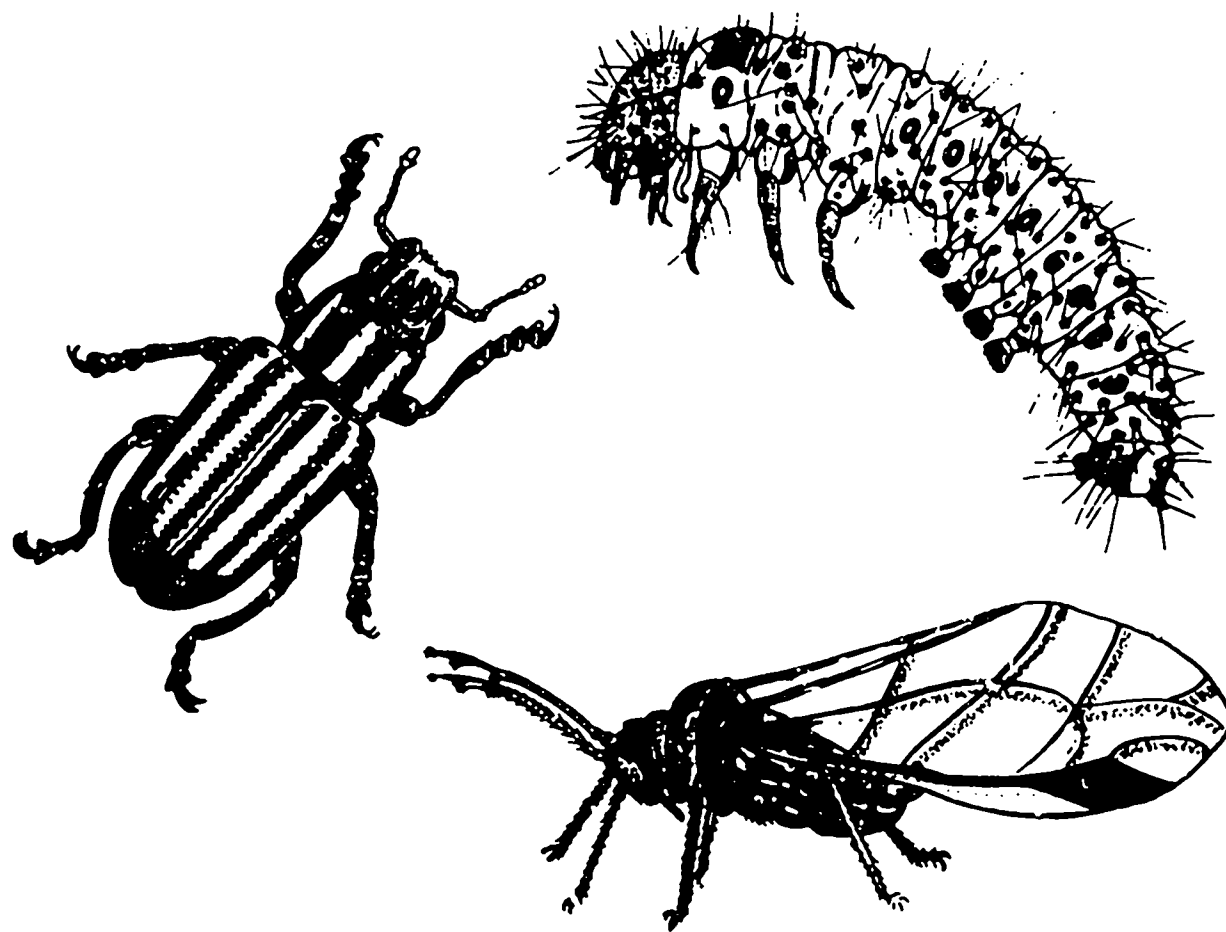


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# INTRODUCTION TO THE MAJOR PESTS OF FOOD LEGUME CROPS IN WEST ASIA



TECHNICAL MANUAL NO: 4



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## **PREFACE**

**This manual has been prepared specifically as background information for trainees in food legume improvement at ICARDA. It represents a compilation of up-to-date information on the major pests causing economic damage to food legume crops in the West Asian Region.**

**It should be emphasised that the manual as currently published only represents a foundation which will be regularly revised and modified in line with the changing base of knowledge on the subject and the developing needs of trainees. Through a continuous cycle of evaluation by both researchers and trainees, such revisions will, it is hoped, ensure that the manual retains its maximum applicability and utility.**

**Throughout the manual emphasis is placed upon the applied considerations essential to the identification of the causes of field damage and to the development and implementation of methods designed to reduce this damage.**

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## INTRODUCTION

The environmental changes brought about by man through agriculture have eliminated a large number of animal species from their natural habitats. Those few species that have survived these changes have done so by altering their living and feeding habits to conform with the new environmental conditions. The practice of monoculture has to a certain extent facilitated this adaptation for a number of species and their feeding has since caused considerable damage to crop plants and consequently high yield losses.

It is these animal species which, because of the destruction that they cause to his crops, man refers to as pests. Animals ranked as pests belong to four main groups of the animal kingdom, namely the Arthropods, the Nematodes, the Molluscs and the Chordates. Of these the Arthropod and Nematode species are, without doubt the most important in terms of their numbers and the crop losses that they cause.

The Phylum Arthropoda contains the insects (Class Insecta), the mites (Class Arachnida), the millipedes (Class Diplopoda) and the woodlice (Class Crustacea). The Phylum Nematoda contains only one class, the eelworms. The Agricultural pests contained in the other two phyla, and

✓

in general of lesser importance than either the Arthropods or the Nematodes, include slugs and snails (Mollusca) and birds and mammals (Cordata).

In studying any animal which feeds from agricultural crops, whenever or whatever damage results, it is essential to achieve a comprehensive understanding of both the animal and its habits before attempting to evolve ways of limiting its numbers and thus of minimising the crop damage and yield losses that it causes. In this way control measures which are of long-lasting effectiveness and which cause as little disruption as possible to the overall ecological balance may be developed systematically from a solid base of knowledge.

For this reason this manual sets out to provide a broad picture of the major types of crop pest and their structure, growth and development and modes of living, within which the individual pests of particular importance to food legumes in western Asia are stressed, giving details of identification, damage caused, habits and life cycles. Measures that are used or that may be useful in the control of these pests are then discussed against this background of pest structure, habits and life cycles.

**INSECTS IN GENERAL**

Pests of the Class Insecta are perhaps the most successful of all the animals that live off man's crops, exceeding all other pests both in species and in numbers. A large number of different species have been observed infesting food legume crops throughout western Asia and many of these frequently cause very appreciable damage to these crops, which are so essential to the diet of the region's population. The undoubted success of the insects may be attributed to a number of characters that they possess:-

1. - Small size: resulting in low food requirements and the ability to avoid predators and extremes of weather.
  2. - Rapid reproductive rate: ensuring that they take the maximum advantage of the brief opportunities available for their increase.
  3. - High mobility: giving great advantages in seeking food, shelter and favourable breeding grounds.
  4. - Wide adaptability: enabling them to invade a vast range of different environments, entering a seasonal dormancy when conditions are adverse, to emerge and grow in synchronisation with their food supply when the environment again becomes favourable.
  5. - Superior body structure: resulting in efficient water and nutrient conservation, and combining strength with lightness.
- 1



### Insect Structure

The insect body is divided into three regions: the head; the thorax; and the abdomen; each made up of ring-like segments. The head consists of segments modified and specialised for sensory perception and obtaining food; the thorax for movement (three pairs of walking legs and, in the adult, two pairs of wings being present); and the abdomen for reproduction. This basic structure can be seen in all insects, whether immature or adult, although considerable variation in form obviously occurs in this very widely distributed group of animals

### Insect Reproduction, Growth and Metamorphosis

In most insects reproduction involves a sexual phase and the production of eggs. However some insects reproduce parthenogenically, producing young without fertilisation; the young all being female and borne alive (as opposed to in eggs), thus ensuring a very rapid rate of reproduction during favourable conditions.

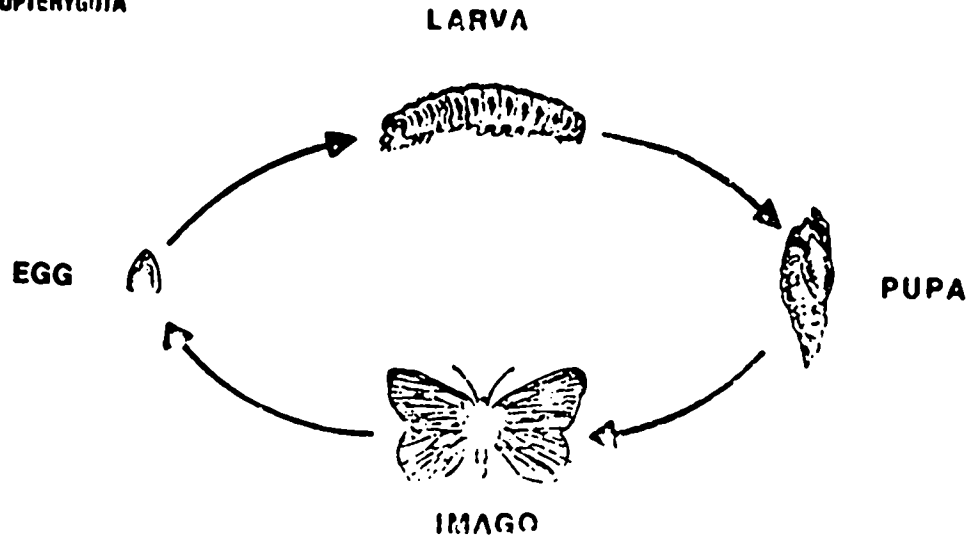
With the exception of some of the more primitive species, all insects undergo metamorphosis (a change in form) as they grow and develop into adults. Young insects emerge from their eggs at different stages of morphological development in different species and thus require different degrees of metamorphosis to achieve the adult form. On this basis insect species may be divided into two groups:-

ENDOPTERYGOTA - in which the young are relatively underdeveloped and take the form of larvae which require a profound metamorphosis (pupal stage) to reach adulthood. (Figure 1 a).

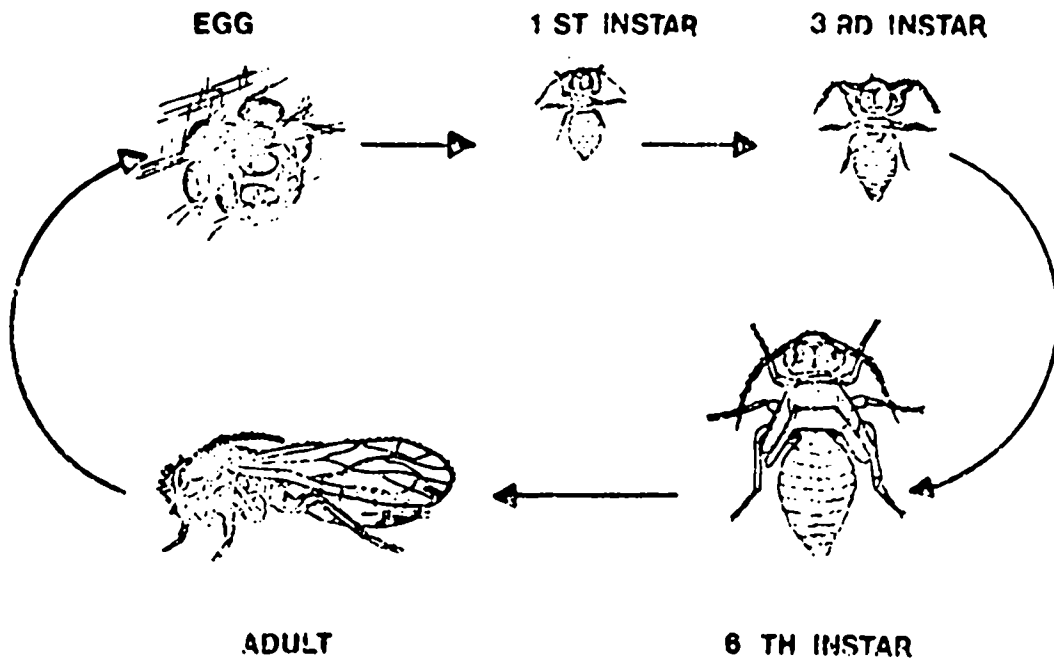
**EXOPTERYGOTA** - in which the young are more developed, usually resembling the adults in form (nymphs) and requiring relatively little metamorphosis before becoming adult. (Figure 1 b).

**FIG: 1 TYPICAL INSECT LIFE CYCLES**

**A. ENDOPTERYGOTA**



**B. EXOPTERYGOTA**



Larvae often differ greatly in appearance and mode of life from the adults. Their relative morphological immaturity has meant that they have to live in a very different way to the adults in order to survive (often in concealed positions to escape predators) and thus that they have developed their own structure and form specific to their needs, (and usually very different to those of the adults). Three different types of larval form are generally recognised:-

Oligopod: These larvae live on the soil surface and may travel over relatively large distances. They are often predators of other insects. To fit this life style they have well developed sensory organs (antennae and simple eyes), heavy biting mouthparts, and strong flexible legs. They are generally coloured to match the soil surface.

Polypod: These larvae are less active than the oligopods and live on or near their food source (usually vegetable). They thus have less well developed sensory organs, only simple mouthparts and reduced thoracic legs. Abdominal 'legs' are also present as these facilitate movement on plant hosts. The colouration of these larvae usually camouflages them well against a background of plant material.

Apodous: Living within or entirely surrounded by their food source, or in the relative safety of the soil these larvae have no legs and drastically reduced, if any, sense organs. They are usually yellow/white or colourless as they require no protection from predators.

Nymphs, with their greater, degree of morphological development, generally have a life style similar to their adults and thus resemble them fairly closely. However in common with all young insects they do not have wings and are sexually immature.

### Crop Injury

The growth and development of young insects is usually fairly rapid as evolution has ensured that only those forms which complete the immature and vulnerable stages with the maximum possible speed survive. To support this rapid development the young insects must consume large quantities of food and it is for this reason that it is the larvae and nymphs that normally cause most of the crop damage attributed to agricultural pests of this class.

The crop damage caused by insect pests may, in general be divided into two main categories:-

- Direct damage, which is a product of the feeding of the insect and which results from either the piercing and biting of plant tissue (direct mechanical damage) or the sucking of plant juices (direct physiological damage). Direct damage is manifest in the field by loss of leaf area, leaf drop, plant distortion, leaf yellowing, general wilting and plant collapse.
- Indirect damage, which results from the secondary invasion of the host plant by various micro-organisms either through the wounds caused by direct mechanical damage after the insect has left the site (mainly fungal and bacterial pathogens) or during the feeding of the insect (mainly viruses). The symptoms of indirect damage relate to those micro-organisms which are responsible for it and generally consist of plant decay, wilting and collapse (over time) or systemic yellowing, blotching or mosaicing.

Insect Pest Classification \*

<u>Division</u>	<u>ENDOPTERYGOTA</u>	
<u>Order</u>	Lepidoptera -	Butterflies and Moths <u>PEA MOTH, CHICPEA PODBORER</u> <u>CUTWORM , ARMYWORM.</u>
	Coleoptera -	Beetles, <u>PEA LEAF WEEVIL</u> <u>PEA WEEVIL, BROADBEAN WEEVIL</u>
	Hymenoptera -	Bees, Wasps and ants
	Diptera -	Flies <u>BEAN FLY</u>
	Siphonaptera -	Fleas
<u>Division</u>	<u>EXOPTERYGOTA</u>	
<u>Order</u>	Hemiptera -	Capsids, leaf hoppers, aphids, scale insects and mealy bugs. <u>PEA APHID, BEAN APHID,</u> <u>LEAFHOPPER.</u>
	Orthoptera -	Cockroaches, crickets grass- hoppers and Locusts. <u>MORE</u> <u>CRICKET.</u>
	Dermaptera -	Earwigs
	Isoptera -	Termites
	Anoplura -	Lice
	Thysanoptera -	Thrips. <u>PEA THRIPS</u>

(\* Pests of particular importance to legume crops in western Asia  
UNDERLINED).

LEPIDOPTERA

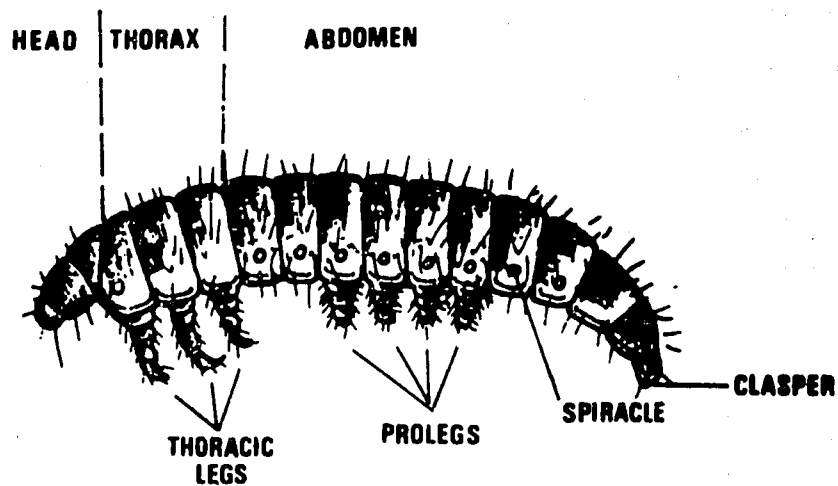
The Lepidoptera is a large order containing many species of economic importance to the agriculture of western Asia. Although there is considerable superficial variation the structure and habits of both the adults and the young (larvae) are remarkably uniform. The adults typically feed on nectar and are capable of prolonged flight, travelling over great distances if necessary. In contrast the larvae, known as caterpillars (of the polypod type), are fleshy and sluggish and, with a few notable exceptions (e.g. armyworms), rarely stray far from their food source. Because of their mouthparts (designed for sucking nectar) and their mode of feeding the adult Lepidopterans cause little damage to crops. The caterpillars however are voracious feeders; and, living on the surface of the host plant (armyworms), in concealment within the plant (pod-borers) or in the soil near the plant (cutworms), are responsible for the widespread and severe crop damage for which the Order is known.

The adults may be observed within a crop, but the identification of the pest and the assessment of potential threat depends primarily upon correct identification of the larval stage and its abundance. All

Lepidopteran larvae have a characteristic structure and are easy to identify on this basis (Figure 2). The main distinctive features are:-

- A well sclerotised head with biting mouthparts
- Three pairs of walking legs
- Four pairs of false legs (pseudopodia)
- A clasper on the last body segment

FIG. 2. LEPIDOPTERAN LARVA



### Armyworms

Armyworms are the larvae of a number of Noctuid moths, which when present in sufficiently large numbers to exhaust their food supply move together in large groups in search of fresh food sources. Legume crops are infested primarily by the larvae of Spodoptera (Laphygma) exigua.

#### Importance and Occurrence

Spodoptera exigua is widely distributed throughout western Asia and has been reported infesting crops in Syria, Palestine, Turkey, Cyprus, Lebanon, Saudi Arabia, Iran, Yemen, Iraq, Jordan, Egypt and Sudan. It is highly polyphagous and feeds upon a wide range of different plant species, but economic damage is primarily confined to the legumes and maize. In some years, when the larval population becomes extremely large, complete crop devastation results, but in general this pest only causes minor damage and is not considered to be of major regular importance.

#### Type of Damage

The larvae begin to feed immediately after hatching; consuming at first only the tender leaf laminae and avoiding the tougher midrib and larger veins, but feeding on the whole leaf and in some cases even the young shoots as they grow and develop. Feeding takes place almost exclusively at night (the larvae retire to hide in the soil during the day), and serious attacks can result in total defoliation of the crop.



### Identification

The adult moth is small, with a wingspan of between 25 and 30mm. The body is gray-brown in colour matching the forewings, while the hind wings are semi-transparent and marked with dark margins and veins.

The caterpillar is light green with conspicuous dark stripes running the entire length of the body, on the back and on the sides. It may reach up to 30mm in length when fully grown.

### Life Cycle

The insect may overwinter in the form of the adult moth, the caterpillar or the pupa depending upon the severity of the weather conditions. As a rule the adults may first be observed in the spring or summer, and upon emergence from the pupa both male and female appear to be sexually mature. They copulate and the female begins laying her eggs in about one day; the eggs are usually laid in large batches (often greater than 100/batch) and in her lifetime of 10 to 20 days the female may lay several batches. The caterpillars hatch in approximately 5 days and attain their full size after feeding on the host for about 10-12 days. They then retire permanently to the soil and pupate just below the surface. The pupal period varies between 6 and 10 days after which the adult moths begin to emerge. Five generations are probably completed in each year.

### Control \*

Cultural methods, especially adequate weed control, may be used to reduce the numbers of insects in a crop. This is because some weeds are also infested by the pest and may be preferred for egg laying.

\* See Section III

Methods of chemical control, such as the laying of poison baits on the soil surface, or the spraying of contact insecticides (except parathion) or stomach poisons, when the signs of feeding are first evident on the leaves, are also commonly used to reduce infestations to a tolerable level. Contact insecticides are successful because the caterpillars feed in an exposed position and stomach poisons due to their large and diverse appetite.

### The Chickpea Podborer

Also Noctuid Moth larvae, pod borers (Heliothis armigera and H. peltigera) are variously known as corn earworms, tomato fruitworms, tobacco budworms, cotton bollworms and vetchworms, depending upon their location and hosts.

### Importance and Occurrence

As their diversity of names suggests podborers are very widely distributed throughout the world and in their host plants. In Western Asia they are an economic pest of chickpeas, lentils, beans, peas, sweet corn, maize, cotton and tomato in particular. Infestations are not normally serious, but considerable damage may be done to the seeds of chickpea, rendering a large percentage unmarketable. Late planted chickpeas may escape damage, but this practice incurs appreciable yield reductions in itself.

### Type of Damage

The economic damage caused by this pest results from the feeding of the larvae, which is almost exclusively confined to the developing seed within the pod. This produces pods containing half eaten seeds and excreta which considerably reduce the market value of a crop.

### Identification

The adult moths are fairly large (wing spread approximately 37-40mm) and light brown in colour. The hind wings are lighter in colour with a conspicuous dark brown band at their margins.

The caterpillars reach a length of about 38-40mm and are very variable in colour; ranging from green to almost black. However a pale lateral band can always be observed running down either side of the larvae, with a darker band in its centre (Plate 1).

### Life Cycle

Both H. armigera and H. peltigera normally overwinter in pupal forms. The adults emerge and appear in the crops towards late April/early May. They are sexually mature at emergence and given adequate temperature copulate immediately. An average of 600 eggs are laid singly on the leaves of host plants over a period of 2 to 3 weeks. The caterpillars hatch after about 4 days and feed briefly on the leaves before boring into the developing fruits, where they remain for about 20-25 days. After this time, when the larvae are fully mature, they leave the fruits and drop to the ground to pupate in the soil surface. A new generation appears in about 15 days and the insect thus has several generations per year.

### **Control**<sup>\*</sup>

To prevent economic damage this pest must be controlled early in the season before it enters the pods (once the larvae are within the pods the damage is already done and they are protected from sprays). With heavy infestations chemical control is vital and a number of contact organophosphate and carbamate insecticides are effective if used sufficiently early, when the larvae are exposed on the leaf surface.

It has been found (in West Bengal) that the degree of infestation and hence yield loss increases proportionately to the delay in sowing, primarily because early sown crops are past the critical flowering stage to which egg-laying is largely restricted by the time the adult moths have appeared. Cultural control, through earlier planting of chickpeas, thus appears to be a possibility.

Screening for resistant chickpea varieties is currently being carried out in India, both at the Indian Agricultural Research Institute (IARI) and at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and a number of varieties showing less than 5% of the pods damaged have been identified to date. Further screening is without doubt necessary before any firm recommendations can be made but the future for the production of resistant varieties appears to be promising.

<sup>\*</sup> See Section III

### Cutworms

Cutworms, in common with army worms, are the caterpillars of a number of Noctuid moths. The most important species infesting legume crops throughout western Asia are Agrotis ipsilon (the greasy cutworm) and A. segetum, (the winter cutworm). Other species, such as A. flammata and A. spinifera have also been observed.

### Importance and Occurrence

Cutworms are highly polyphagous ; attacking a wide range of plant species, including legumes, cotton, corn and tobacco. They have been reported infesting crops in Syria, Lebanon, Palestine, Turkey, Jordan and Egypt and when present in sufficient numbers cause appreciable crop damage.

### Type of Damage

Cutworms may injure plants in several different ways; some species (A. ipsilon) kill the plant by cutting off the stem at the crown or a short distance below the surface, moving about and damaging several plants, while others (A. segetum) spend a period of feeding on the upper leaves before moving to the soil surface as they mature and eating the stems as in the former case. In severe outbreaks the caterpillars appear in hordes, cutting off plants and eating them completely before moving to fresh sources. In such cases the crop may be totally devastated by the pest.

### Identification

The adult moths are grey-brown and fairly large (wingspan approximately 35 -50 mm). The forewings are light brown and patterned, while the rearwings are pearly white and marked with dark margins and veins.

The caterpillars of A. *ip*silon are bright green in colour when young, becoming darker green as they mature, and are marked with two bright lines running their whole body length . The caterpillars of A. *segetum* are, like those of A. *ip*silon, smooth and cylindrical in shape with no body hairs, but in contrast are a dark grey colour. (Plate 1) Fully grown caterpillars of both species reach about 40mm in length.

### Life Cycle

The insects overwinter either in the pupal stage or as a fully grown caterpillar in a cell in the soil. By mid-April adult moths appear, copulate and lay their eggs (the timing being dependant upon temperature). Up to 2000 eggs may be laid, either singly or in small batches during the female moth's lifetime. The eggs, which are usually laid on the lower leaves of host plants, hatch after about 7 days (3-4 days in A. *ip*silon). The larvae of A. *ip*silon feed almost exclusively on the plant stems at about the soil level and then pupate in the soil. The larval stage varies from 18 days at 27°C to 65 days of 15°C. This is similar for A. *segetum* larvae, which feed mainly on the undersides of the lower leaves when young and on the stems as they mature. Several generations are thus produced per year.

### Control<sup>\*</sup>

Control of cutworms is made more difficult by the fact that many species live most of their lives below the soil surface. The method most commonly used involves poison baits and is successful due to the unspecialised feeding habits of the caterpillars, which wander over the soil surface in search of food. BHC together with bran or beet pulp, moistened with water and spread in the afternoon, has been found to give 80% control and is thus recommended. DDT, aldrin, dieldrin and other insecticides can also be used as either dusts or sprays and where trouble is anticipated should be applied to the soil surface a week before planting.

### The Pea Moth

The pea moth, Laspeyresia nigricana, is one of the small Tortrix moths occurring in temperate regions.

### Importance and Occurrence

L. nigricana is found throughout the Mediterranean countries, in Syria, Lebanon and Palestine. It is primarily a pest of field and garden peas, sweet peas and vetch. In common with Heliothis armigera it causes severe reductions in both seed quantity and quality of infested crops.

### Type of Damage

The caterpillars, like those of the chickpea podborer, attack the seeds inside the pods and are not easily detected unless the pods are opened. The feeding of the caterpillars results in pods filled with spoiled seed, excreta and the silken webs of the larvae (Plate 1.). In addition secondary damage may be caused by fungal infections of seeds not actually damaged by the caterpillars. Field surveys of damaged pods (500) undertaken during 1978 at Aleppo (Syria) have indicated that up to 98.8% of the pods and 73% of the seeds may be damaged in this way.

### Identification

The adult moth is small (wingspan approximately 15mm) and delicate. It is brown in colour with short oblique black and white lines along the front margins of the fore-wings.

The caterpillar is yellowish white with small dark spots and short hairs scattered over the body. It reaches about 13 mm in length.

### Life Cycle

Overwintering takes place in the larval stage inside silken cocoons just below the soil surface. In late spring the larvae pupate and the adults appear within the crop as the peas begin to blossom. The emergence of the adults is kept in step with the growth of the crops by a period of dormancy through which the larval stage passes in the soil and which is broken by cold. Copulation occurs and the eggs are laid over the exposed parts of the plant singly or in batches of two or three.



The tiny caterpillars hatch after 8 days and bore into the developing pods directly, leaving no noticeable point of entry. They remain in the pods, feeding from the seeds, for about 17-20 days, after which they emerge, fall to the ground and burrow into the soil where they spin cocoons and hibernate through the winter.

#### Control \*

Pea moth attack is determined by four main factors, namely; the flowering time of the crop variety; the egg laying time of the adult moths; the crop density; and the available shelter. The intensity of infestation may thus be considerably lessened by simple cultural measures, such as: avoiding the planting of peas after peas; sowing early, quick maturing varieties (which are past their susceptible flowering stage when the adults emerge); and cultivating and ploughing deeply in autumn (to disturb and bury the overwintering larvae).

Peas may be protected at the susceptible stage by a spray of DDT, which kills the adults and wandering larvae and remains active as a residual film for several days. However this often fails to give full control and a second application may be necessary after about 14 days if infestation in crops to be harvested dry is severe. Control is complicated by the fact that the caterpillars emerge from their eggs and are susceptible to contact insecticides on the plant surface (before entering the protection of the pods) at different times.

\* See Section III



Cut worm larvae



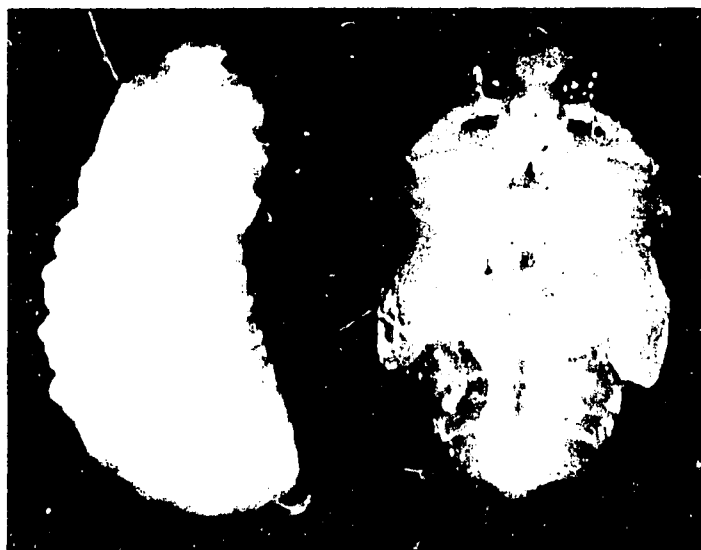
Pod borer larvae  
(*Heliothis* sp.)



Bud weevil adult damage ( *Apian* sp.)



Leaf weevil - sitona sp.



Faba bean seed  
beetle.  
Larvae and pupa

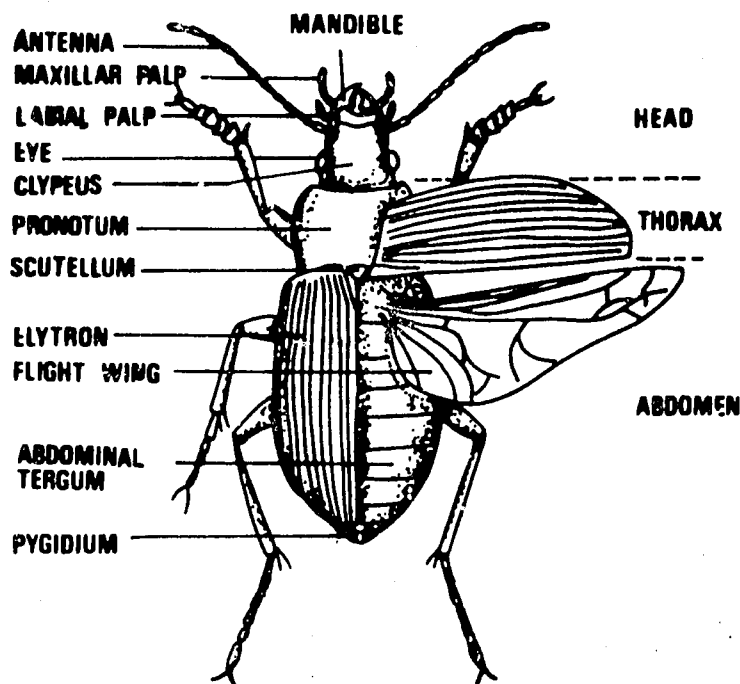
COLEOPTERA

The order Coleoptera is one of the largest in the animal kingdom and contains many species considered to be important agricultural pests (e.g. wireworms, pollen beetles, mealworms, seed beetles, colorado beetle, flea beetles, chafers and leaf weevils), as well as some (ground beetles and ladybirds) which are carnivorous and consume other insect pests and are thus considered beneficial.

Economic damage is caused to a wide range of crop species both in the field and in store by both the adults and the larvae of these insects. However the identification of the pest depends primarily on the identification of the adult stage. Although species vary greatly in size and habits, the overall adult structure is fairly uniform (Figure 3) and possesses a number of features which are important in identification:-

- Mouthparts heavy and adapted for biting;
- The foremost body segments formed into a hard and shell-'pronotum';
- The forewings modified into hard wing cases (elytra), which are held outstretched in flight.

FIG. 3. COLEOPTERAN ADULT



### Leaf Weevils

A number of genera of the family Curculionidae are important pests of leguminous crops in western Asia. The most damaging of these insects are species of the genera Apion, Sitona, Hypera and Lixus.

Clover Apion (A. aestivum) and Legume Apion (A. arrogans) may cause considerable damage to leguminous crops; the adults feeding from the leaves and young shoots and the larvae feeding within the ovules and developing seed.

The alfalfa weevil (Hypera postica) is another leaf weevil which is widely distributed throughout west Asia and which is responsible for appreciable crop losses in legume crops. Although the main host is

alfalfa, lentil crops in Syria have been attacked since 1970 and the consumption of the leaves by both adult and larvae seriously damages infested crops.

Lixus sp. (stem borers) are primarily a pest of broadbeans and the larvae which bore into and feed from the succulent stems of this crop have been observed to cause losses of up to 30% in the region. Until recently many of the crop losses actually due to infestations of Lixus sp. have been attributed to organisms of the wilt complex.

Without doubt however the most important and damaging of the leaf weevils are the Sitona species (S. lineata, S. limosa, S. crinitus and S. lividipes). Of these the most widespread pest is the Pea Leaf Weevil (Sitona lineata).

#### Importance and Occurrence

Sitona lineata has been observed infesting legume crops throughout Syria, Lebanon, Iran, Turkey, Palestine, Cyprus and Iraq and its most common hosts are peas, beans, lentils, broadbeans, chickpeas, vetch, alfalfa and clover. The insect causes considerable damage to young seedlings, but more mature plants can 'grow out of' most infestations.

#### Type of Damage

The adult beetles feed on the host plants by chewing small crescent shaped notches from the leaf margins (Plate 2). Attacks on seedlings may result in almost total defoliation and consequently drastic yield reductions, but the effects are less severe in older crops.

The larvae are soil living and feed upon the plant roots and their nitrogen fixing nodules, thereby adversely affecting the crop's supply of nitrogen and facilitating the entry of organisms which cause decay and may thus destroy the whole plant.

### Identification

The adult is about 4-5mm in length. It is dark in colour and covered with a dense coat of short hairs, which give it a brownish grey appearance. Alternating dark and light bands cover the pronotum and elytra, running along the length of the insect. It is characterized, as are all weevils, by an elongated snout from which the jointed antennae protrude (Plate 2.).

The larva is between 5 and 6mm in length, and is grub-like and legless. Its body is white, with the exception of the head which is brown in colour.

### Life Cycle

S. lineata overwinters in the adult form; the adults emerging from their dormancy period in November/December. Feeding starts at about this time and after approximately two weeks copulation takes place and the females lay their eggs in the soil close to host plants. An average of 1,800 eggs are laid (the maximum may be up to 4,500) and the incubation period varies between two and four weeks depending upon the environmental conditions. The newly hatched larvae crawl into the soil and feed on the roots and root nodules, where they remain until pupation about five to six weeks later. The pupal period lasts from 9-21 days and is dependant upon soil temperature; the new generation usually appearing in mid-July. However it enters into diapause until the following November and there is thus only one generation per year. The adults are long lived and may still be observed in the crop as late as June.

### Control \*

The adult beetles should be controlled as soon as they appear in the young seedling crop, in order to reduce seedling damage and the number of insects that can reproduce and produce eggs. Many of the contact organophosphorus insecticides are effective against this insect.

### Seed Beetles

The second major group of Coleopteran pests of legume crops comprises species of the family Bruchidae (seed beetles). A large number of different species, all primarily pests of stored grain, are important. These include:-

- The Bruchus species, such as B. pisorum (the pea weevil), B. rufimanus (the broadbean weevil) and B. ervi and B. lentis (the lentil weevils), which infest all the legume crops and only have one generation per year;

- The Callosobruchus species, such as C. maculatus (the cowpea weevil) and C. chinensis (the cowpea beetle), which attack lentils, broadbeans and chickpeas as well as their primary host (cowpea) and can be particularly damaging as they reproduce and have several generations in stored seed;

- Acanthoscelides obtectus (the bean weevil), another potentially damaging beetle with several generations per year.

Of these the Bruchus species are without doubt the most important pests of stored legume seed in western Asia. Callosobruchids, although less damaging in general, appear to have great potential as very serious pests and thus also deserve consideration.

\* See Section III



### Importance and Occurrence

Seed infestations of up to 80% have been recorded as arising from these beetles in stored lentils in Syria. They are also important pests in Lebanon, Turkey, Iran, Iraq, Jordan, Palestine and Egypt and cause appreciable economic losses in almost every season.

### Type of Damage

Damage is caused almost exclusively by the larvae which feed upon the seed, thereby reducing its feed value, acceptability and germination potential. In the early stages of infestation seed damage is slight, but losses can be extremely serious if seed is stored over prolonged periods, allowing the larvae to develop fully and, in the case of Callosobruchus species, to multiply. (Plate 2.)

### Identification

Although the larval stage is largely responsible for the economic damage caused by these pests, their identification depends primarily upon identification of the adult insects.

The adults of Bruchus species are small (3-5mm in length). They are generally dark in colour (black or brown) with a covering of fine white or grey hairs. Callosobruchus adults tend to be smaller (2-4.5 mm in length) and more slender with a dark to light brown body. Individual species bear characteristic markings on their elytra (Plate 2.).

The larvae are in general off-white/yellow in colour, with a dark brown head. They are curled and grub-like and reach about 5 to 6mm in length.

### Life Cycle

The seed beetles overwinter in stored seed or crop remnants in the field and their emergence is timed to coincide with the flowering of the host. Upon emergence the adults feed on the pollen of the host flowers

and after copulation lay eggs on the surface of the developing pods. The incubation period varies with temperature and species, and the larvae bore into the pods immediately after hatching.

Bruchus species only have one generation per year and the larvae take about 33-45 days to mature inside the stored seed. They then pupate within the seed and after about 14 days the adults emerge, often remaining within the seed cavity for some time. The entire life cycle lasts about 7-8 weeks.

In contrast Callosobruchus species may complete one generation in less than three weeks and the adults, emerging in the stored grain then proceed to lay more eggs directly onto the seed. In this way up to eight generations may be produced per year if storage is prolonged. At low temperatures however the speed of larval development is reduced and fewer eggs hatch; thus the number of generations and the degree of damage is also considerably reduced.

#### Control \*

The control of field infestations will obviously considerably reduce the severity of damage in store, especially with the species that only have one generation per year. The removal of plant remnants by ploughing under or burning is very effective in controlling adults overwintering in the field and those overwintering in the seed may be eliminated by seed dressings so that only clean, bruchid-free seed is planted. If adults are observed within the crop sprays of contact organophosphorus insecticides should be applied to the plants at the early bloom stage (before egg-laying). After harvest the seed should be treated before storing.

\* See Section III

Infestations in store, which can develop rapidly from low levels of primary infestation in species able to reproduce in stored grain, may best be controlled by fumigation. Chemicals such as camphor and naphthalene (providing that the seed is not for consumption) have been found to be very effective in this regard. It has also been shown that the addition of small quantities of vegetable oil to stored grain can give good control of storage pests and this, together with some degree of control over storage temperature and moisture content (to slow down the development and multiplication of the pests), constitutes a simple but effective and low cost means of reducing damage.

The development of legume varieties resistant to bruchids is also a promising possibility. Resistance has been reported in lentils, but is at present unfortunately associated with poor cooking quality. In chickpeas studies have indicated that rough and spiny seed coats are avoided by Callosobruchus adults when egg laying. The use of such characters as this may be of great assistance in developing varieties resistant to these important pests.



*Callosobruchus chinensis* damage



Leaf weevil (*Sitona lineatus*)

## CHAPTER 4.

### DIPTERA

This is a large Order of highly specialised insects. The adults are normally strong fliers and distinguished by having only one pair of wings (the hind pair having been lost in evolution). The head is highly developed, possessing compound eyes. (in the more advanced dipterans the antennae are considerably reduced) and mouthparts modified for piercing and sucking or for sucking only. The larvae are apodous and very highly simplified for feeding either within plants or within the soil. The Diptera is divided into three sub-orders: the lower Diptera or Nematocera (e.g. gnats, mosquitos, gall midges, crane flies and hibionid flies); the middle Diptera or Brachycera (e.g. horse flies, clegs and robber flies); and the higher Diptera or Cyclorrhapha (e.g. hover flies, frit fly, gout fly, agromyzid flies, house fly, wheat bulb fly and cabbage root fly). The Cyclorrhapha is relatively more advanced and highly specialised than the other two sub-orders and contains most of the species of major importance to agriculture.

Both the adults and the larvae of the main agricultural pests of this class are very small and difficult to see. Identification is thus primarily dependant on the observation of infestation symptoms in the crops. Once symptoms have been observed the affected part of the plant may be

opened to reveal the larvae, which are almost exclusively responsible for the crop damage, and an accurate diagnosis can thus be made.

Legume crops in western Asia are affected principally by only one group of Dipteran pests, the Agromyzidae.

### Leaf Mining Flies

A number of species of agromyzidae infest the leaves of leguminous plants throughout west Asia. Of particular importance are the bean fly (Melanagromyza phaseoli), the broadbean fly (Liriomyza trifolii), the chickpea fly (L. cicerina) and the pea fly (Phytomyza atricornis). All these species produce similar symptoms and have a similar life cycle and so only one, the bean fly, will be described here.

### Importance and Occurrence

M. phaseoli is found mainly in Syria, Palestine and Egypt and is not considered to be a pest of major importance, although appreciable crop damage may result if infestations occur on a large scale. Host plants include beans, chickpeas and soybeans amongst others.

### Type of Damage

The larvae feed by tunnelling through the leaves, consuming the mesophyll and palisade layers but leaving the epidermal layers (Plate 3). Once they reach the stem they mine into it and continue moving downwards. The feeding of the larvae enable rot causing micro-organisms to penetrate the plant and these can lead to tissue breakdown and wilting.

### Identification

The adult fly is only 2mm in length and its outspread wings measure about 4.5 mm. The body is generally dark in colour.

The larvae reach a maximum length of 3mm and are a creamy white in colour.

### Life Cycle

The insect may raise several generations per year; the time required to complete each generation varying from 12 days in the summer to 19-26 days in the autumn. Overwintering takes place in the pupal form either in the soil or in crop debris on the soil surface. Upon emergence, usually in late April, the adults copulate and the female lays its eggs within the tissues of the host leaves just below the upper epidermis. These eggs hatch in about two to three days and the larvae mine throughout the leaf and its petiole, eventually reaching the stem where they continue tunnelling downwards until they attain their full size. At this point they pupate within the stem, usually in groups of three or four. The pupal stage normally lasts approximately nine days, after which the adult emerges through the thin outer layer of stem tissue which still separates it from the outside. Other agromyzid species may pupate in the soil rather than inside the stems of their hosts.

### Control \*

Chemical control of agromyzid flies is difficult due to the large proportion of their life which is spent protected from chemical sprays within the plant. However sprays of contact insecticides early in the season when the adult flies are abundant combined with the use of granular and foliar systemic chemicals have proved effective in reducing the economic damage caused by this pest.

Good crop hygiene, ensuring the disposal of crop remains by deep ploughing or burning also helps to reduce infestations by eliminating many of the overwintering pupae.

\* See Section III

HEMIPTERA

The Hemiptera is the largest Order of the Exopterygota; containing more than 40,000 species. All its members obtain their nutrition by sucking juices and have mouthparts highly modified for piercing and sucking. The majority are plant feeders, both as adults and as young (nymphs), but some species feed on mammalian blood or from the juices of other insects. The adults possess two pairs of wings (the hind pair may be reduced in some species) and can travel over very great distances, riding on air currents. Because of this mobility and their rapid reproductive rate and specific mode of feeding a number of Hemipterans are considered to be important pests of agricultural crops. Examples include: capsid bugs, plant lice, white flies, mealy bugs, leaf hoppers and perhaps the most important of all crop pests, aphids.

Phytophagous Hemipteran insects feed by inserting their elongated mouthparts (stylets) into the tissue of their host plant. In some species the stylets pierce the phloem and form a tube through which the plant sap is transferred to the insect by the plant's own turgor pressure. In others the stylets are inserted through the plant epidermis and saliva, containing substances that digest plant tissue, is injected; the products of cellular breakdown are then sucked back into the insect.

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**This feeding can cause plant injury in a number of different ways:-**

- The sucking of plant sap (especially when a large number of insects are involved) diverts appreciable quantities of plant nutrients from their destinations and thus results in the death of the plant parts deprived of their nutrition (primarily the fruits);

- The action of piercing and sucking, together with the injection of saliva may produce localised disease symptoms (necrotic and bleached spots, leaf curl or galls) on the infested areas. When the rapidly growing parts of young plants are attacked severe distortion of leaves and stems often results as the plant grows;

- As the plant sap is processed within the insect and the useful nutrients are extracted a waste product which has a very high sugar content (honeydew) is excreted. This provides an ideal medium for the growth of a black fungus (Sooty Mould) which may cover the plant surfaces affected and thereby reduce their photosynthetic ability;

- The specialised mode of feeding, involving the piercing of plant tissue and releasing of saliva within the tissue, is very effective in transmitting harmful micro-organisms (especially viruses) from plant to plant. Viruses, because they are systemic, can affect the whole plant from only one focus and may be very damaging.

Direct injury, resulting from the feeding of these insects, is only caused when they are present on plants in very large numbers. However indirect injury, caused by the transmission of viral diseases may be severe even at low population densities. Such considerations underline the importance of good control of these pests to reduce the crop losses which may result from their infestations.

Only two groups of Hemipteran insects, namely Aphids (Aphididae) and Leaf hoppers (Cicadellidae) are important pests of leguminous crops in west Asia. However both groups are efficient vectors of a large number of viruses and can thus cause considerable economic damage even when present in only small numbers.

### Aphids

This family is considered to be one of the most important groups of agricultural pests. This eminence has been achieved by virtue of a number of features of their structure and habits, which enable them to successfully infest a wide range of hosts over a very wide geographical distribution and act as efficient virus vectors. These features are primarily: their great reproductive ability and rapid rate of maturity (the young nymphs being borne alive and asexually, by parthogenesis, in large numbers and in a relatively mature state); the considerable mobility of their winged forms (which may be transported by air currents over hundreds of kilometers at heights in excess of 1,000 metres); and the form of their mouthparts (well adapted for feeding from a great range of plants and for transmitting viruses).

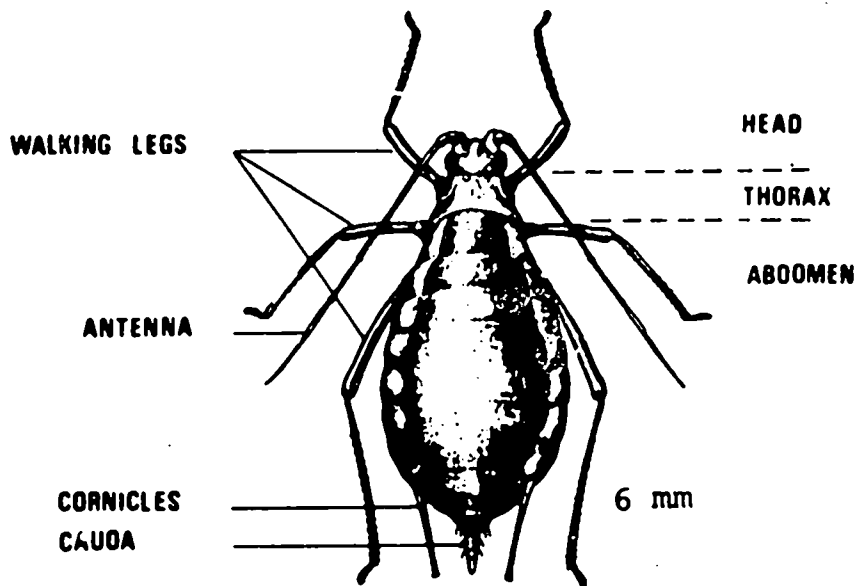
Aphids are characterised by:-

- A pair of organs known as cornicles arising from the fifth abdominal segment;
- A well defined cauda or tail;
- Long antennae; and
- Long tube-like mouthparts; (Figure 4).

Both winged and wingless forms are produced. Wingless aphids remain on the host plant on which they were borne, whereas winged forms are unable to accept this host and thus must migrate to establish new colonies.

A number of aphid species are important pests of legume crops, and although they are in general of less economic importance in western Asia than in Europe considerable damage may be caused by the black bean aphid (Aphis fabae) in broadbeans, the black aphid, (Aphis craccivora) in chickpeas and lentils and the green pea aphid (Macrosiphum pisi) in peas and chickpeas.

FIG. 4. APHID MACROSIPHUM PISI



## The Black Bean Aphid

### Importance and Occurrence

Aphis fabae is very widely distributed and infests all species of leguminous plants in western Asia, both crops and weeds. Vicia faba is the main host of this pest. These crops are attacked invariably every year and in some seasons, where conditions are particularly favourable, appreciable economic injury results.

### Type of Damage

The aphids are found mainly in the terminal growth of the plants, where they suck the sap and cause yellowing of the leaves. Infestations, especially in young plants, of the growing and developing leaves and stems often result in considerable distortion of these parts (Plate 4 ). Honeydew secretions by the insects also host the development of black sooty mould on the plant surfaces and this interferes with the light reception necessary for efficient photosynthesis. Further indirect damage is caused by the insects' ability to transmit viruses such as bean common mosaic, bean yellow mosaic and soybean mosaic, which cause appreciable disease loss.

### Identification

Both winged and wingless forms of adult are found together on infested plants. They are generally dark in colour (varying from black to brown/black and dark olive green), but the wingless female is often of variable colouring. The body length varies between 1.7 and 2.9mm (Plate 4 ).

The immature nymphs are similar in form to the wingless adults, but can be distinguished by the white spots covering their abdomens.

### Life Cycle

Where climatic conditions permit it is common to find bean aphids infesting plants (both crop and weed) all-year round. They continue to reproduce parthenogenetically, producing many asexual generations per year. However in colder areas sexual forms appear in the autumn; they copulate and the females fly to an alternate woody host on which they lay their eggs. In the spring the eggs hatch and produce only winged females which return to their primary host and produce wingless females in abundance by parthenogenesis. As the population density increases on a host plant a greater proportion of winged to wingless forms are produced. Thus the insects spread to other host plants on which they found new colonies of wingless females reproducing very rapidly.

### Control \*

Crop losses may be reduced by the use of certain cultural practices. These include: the early sowing of crops, which enables them to be more mature and better able to withstand damage by the time that aphid infestations become severe; and the removal of weeds and volunteer plants acting as reservoirs of the pest when the principal host is not available which helps to delay the onset of serious infestations until the crops are more mature.

However as aphids are carried over very great distances infestations are bound to occur from migratory adults whatever precautions are taken. Chemical control will thus probably be necessary to prevent crop losses in most seasons. The use of broad-spectrum contact insecticides in the past has resulted in dramatic increases in aphid populations as many aphids protected within the folds of the developing leaves and stems were not controlled, whereas the majority of the species which prey upon them were killed. Certain contact chemicals, however, which

are specific in their action towards aphids are now available and are recommended as they leave the predators unharmed. In order to obtain good control (especially of the insects which are protected from contact chemicals) certain systemic insecticides, which are translocated within the plant and thus transferred directly into the feeding insects, should be used. These may be applied either as sprays or as granules on the soil surface.

In the long term effective and lasting control of the pest and/or its damage will depend upon the evolution of crop cultivars resistant either to the pest or to the viruses which it transmits. Some cultivars have been found to show considerable aphid resistance and breeding work, it is hoped, will be able to transfer this resistance into varieties adapted to the varying local production conditions of the region.

### The Black Aphid

#### Importance and Occurrence

Aphis craccivora, the black or lentil aphid can be found infesting a wide range of different plant species throughout west Asia. Its prime leguminous hosts include: lentils, chickpeas, alfalfa, clover, beans, broadbeans and peas. Although in general less important than A. fabae on broadbeans, this insect may cause appreciable damage to lentils and chickpeas under favourable conditions.

### Type of Damage

Like the black bean aphid the direct damage caused by A. craccivora results from its consumption of plant sap. However this pest has a tendency to feed from the flowers and developing pods rather than on the stems and leaves and this habit can lead to very severe yield losses when it is abundant. In addition the production of honeydew and the transmission of viruses may result in serious indirect crop damage.

### Identification

Both the winged and wingless adult aphids are similar in appearance to the adults of black bean aphid; being black in colour and about 1.5-3.3mm in length.

However the two pests may be distinguished, as the nymphs of A. craccivora are dark green in colour and do not have the characteristic white abdominal markings of A. fabae nymphs.

### Life Cycle

No sexual forms have been observed in the countries of the Mediterranean. The typical life cycle is thus very simple in this region, with females producing young asexually all the year round; the duration of each generation varying with temperature. Overwintering may take place on a number of different host species (either crops or weeds) depending upon their availability.

### Control

\*

As with the black bean aphid, certain contact insecticides with specific action against aphids may be used, together with the more effective systemic chemicals, to reduce infestations or as a protective measure if winged adults have been observed in the crop and it is still at a susceptible stage.

\* See Section III

Various cultural control mechanisms may also be used to escape crop infestation when the plants are still young and thus to minimise yield losses.

### The Pea Aphid

#### Importance and Occurrence

Together with the black and the black bean aphids, Macrosiphum pisi is considered to be an important pest of food legume crops. Unlike A. craccivora it infests only leguminous plants, of which peas, chick-peas, broadbeans, alfalfa and clover are the crops most severely damaged. M. pisi is found in all the countries of western Asia.

#### Type of Damage

The pea aphid is more sedentary than many species and being confined in hosts to leguminous plants tends to form large and smothering colonies which can, under favourable conditions, completely overwhelm the growing points of the hosts and severely stunt their growth. Later infestations affect the flowers and pods and may be very harmful. As a result of its more sedentary way of life such direct damage is often of more significance than indirect damage, caused by its virus transmitting abilities.

#### Identification

The pea aphid may be readily distinguished from the other two species of economic importance to legume production, by its bright green colouration and its considerably greater body size (length about 3.5-4mm).



### Life Cycle

Where climatic conditions are favourable and host plants available M. pisi continues to reproduce parthogenically through the winter months. In the spring the population increases sharply and a number of generations are produced in the spring and summer months. When crowding reaches a critical level winged forms are produced and these migrate to new hosts to produce fresh colonies. As with the black bean aphid, in areas where the winters are cold winged males and females are produced in the autumn. These mature and copulate and the females lay their eggs on the leaves and stems of clover or alfalfa. In the spring these eggs hatch into wingless females which produce a large number of winged offspring asexually. The host crops are thus reinfested.

### Control \*

Systemic insecticides are particularly effective against this highly colonial pest and as in the control of the other aphid species may be used as sprays or in granular form, together with aphid-specific contact insecticides.

Cultural control methods, such as early planting and good crop hygiene, will also help to minimise crop losses.

\* See Section III



Leaf miner,  
larvae damage  
(*Liriomyza cicerina*)



Bud weevil (*Apion* sp.)

## Leaf Hoppers

### Importance and Occurrence

Leaf hoppers are very abundant in field crops and although of considerably lesser importance than Aphids can cause heavy plant damage, especially on non-irrigated crops. One of the most common species attacking all species of leguminous plants in western Asia is Empoasca lybica.

### Type of Damage

Empoasca lybica feeds by sucking the sap from individual cells of the host leaves. Leaves of different plants respond to attack in different ways: some become discoloured; others turn red and the leaf lamina wrinkle; and others still respond by partial or complete yellowing of the leaf blade.

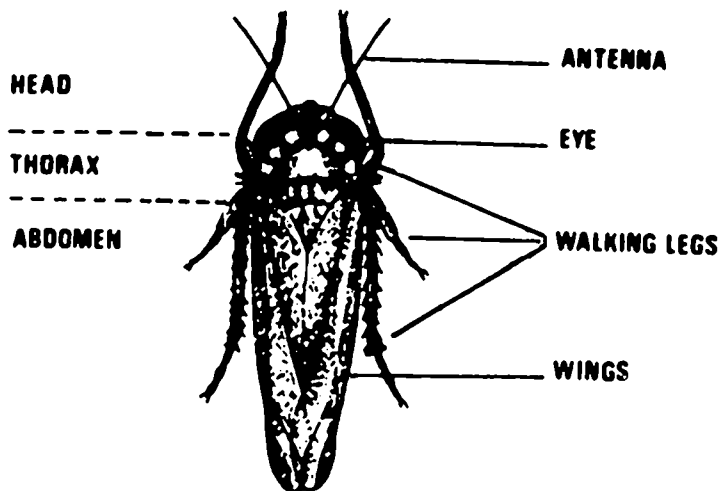
Besides this direct damage, infested plants may also be injured by viral diseases transmitted by the insects.

### Identification

Leaf hoppers are very small and slender insects (reaching about 2-3 mm in length) usually green in colour (Figure 5). They are not readily seen unless in very large numbers and thus identification rests primarily on observations of the symptoms. Examination of leaves showing a variety of distortion and discolouration symptoms will reveal the insects, if they are indeed the cause.

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FIG.5. LEAF HOPPER EMPOASCA SP.



### Life Cycle

The adult females lay their eggs either on the leaves or under the leaf sheaths. The nymphs hatch and while feeding from these leaves pass through six instars, emerging as an adult in about 20 days in the summer. There may be more than one generation per year.

### Control \*

As they feed in exposed positions on the leaves, leaf hoppers are easily controlled by contact insecticides. To achieve good control however the chemical must be sprayed on the underside of the leaves in order to reach the nymphs, which primarily feed in this position. Systemic insecticides are also effective but may be more costly and give an unnecessarily good control.

\* See Section III

## CHAPTER 6.

### OTHER INSECT PESTS

The further Insect Orders, namely the Orthoptera and the Thysanoptera, contain species considered to be pests of legume crops in west Asia. Both the Mole cricket (Gryllotalpa gryllotalpa) and the pea thrips (Kakothrips robustus) may cause significant crop damage in some seasons, but are not of major regular importance.

#### The Mole Cricket

##### Importance and Occurrence

G. gryllotalpa attacks a number of different crop plants, including legumes, brassicas, potato, corn, tobacco and cotton. It is widely distributed, usually more prevalent in warmer climates and can be especially damaging to young plants and seedlings.

##### Type of Damage

Mole crickets are soil living insects and feed from the roots and underground parts of host plants. Attacked plants are physically up-

rooted by the pest before being consumed and, as several plants may be attacked at one time, extensive crop injury may result. These insects are particularly abundant in soils rich with animal manure, and only feed at night.

### Identification

The adult cricket is a weird looking insect, about 45-50mm in length and dark brown in colour. It has short membraneous wings and its first pair of walking legs are short, stout, flattened and specially adapted for digging.

The presence of a mole cricket can be easily detected by the zig-zag cracks that it leaves in the soil as it moves just below the surface.

### Life Cycle

Overwintering in either the adult or nymphal stages in the soil, the insect resumes its activity and development in the spring as the temperature increases. Upon reaching maturity the adults copulate and the female lays her eggs in a special chamber constructed in the soil. Shortly after emerging from the eggs the nymphs commence feeding and causing crop damage, which increases as the insect grows.

### Control \*

Because of their very aspecific appetite mole crickets may be controlled by poison baits applied to the soil where the characteristic zig-zag cracks are visable. The bait, which should be spread in the early evening and preferrably after irrigation to ensure that it does not dry out, normally consists of a stomach poison, mixed with wheat bran, small quantities of molasses and water.

\* See Section III

## The Pea Thrips

### Importance and Occurrence

In the drier areas of western Asia, this pest may be observed infesting pea crops at about flowering time (April). Because thrips appear relatively late in the season crop injury is not generally severe unless the population is very great.

### Type of Damage

The feeding of both the adults and the nymphs causes the affected parts of the leaves, pods and flowers to take on a silvery sheen (resulting from the empty epidermal cells filling with air). Attacks of the flowers and developing pods may cause severe distortions and culminate in reduced yields.

### Identification

Thrips are minute (about 1mm in length) elongate insects, which appear black in colour and are usually found in large numbers in all kinds of flowers. The adults have two pairs of narrow wings, which are absent in the bright yellow nymphs.

### Life Cycle

Thrips normally overwinter in the form of the last instar nymph, which is almost pupal, in the soil. The adults appear in the crops at about flowering time and lay their eggs usually inside the flowers.

The nymphs soon hatch and feed off the flowers and developing fruits during their first two instars. After this they drop to the ground and descend into the soil where they remain to complete their development (the third and fourth nymph instars) before emerging as adults the following year.

#### Control \*

Good control can be achieved chemically by using contact insecticides under dry conditions to give maximum persistence on the plants. Rainfall in any case is unfavourable to the insects and attacks may be terminated by a late rain day or by irrigation if practised.

\* See Section III



## CHAPTER 7.

### OTHER ARTHROPODS

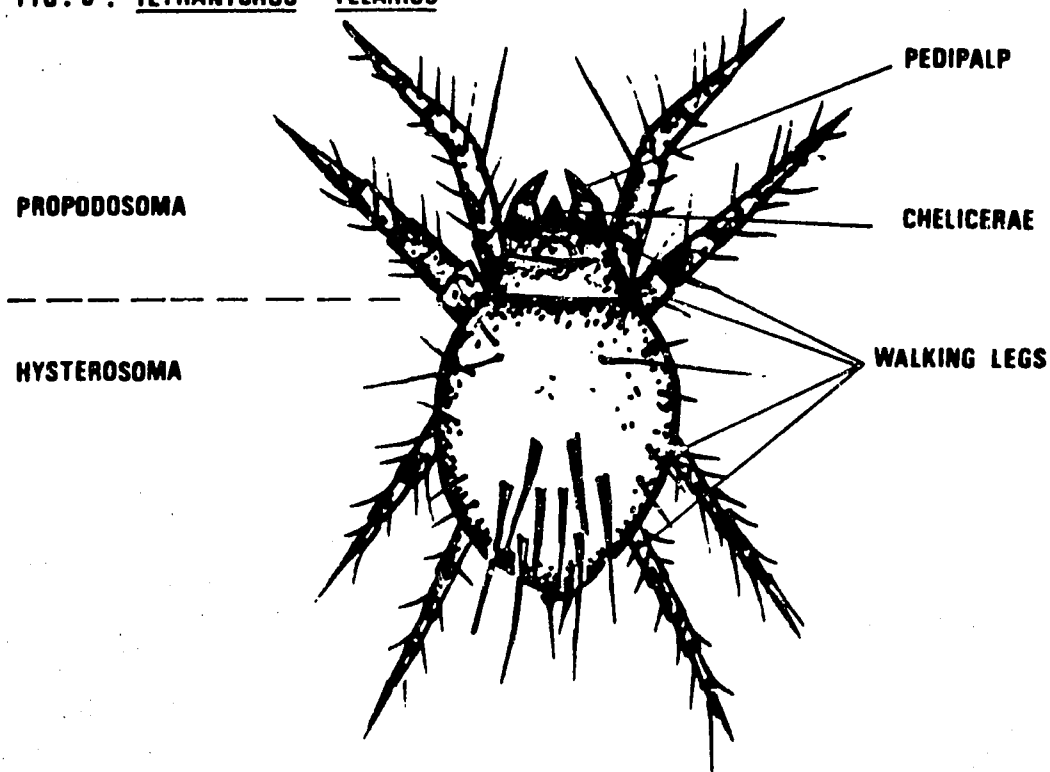
Aside from the Insects the only other Arthropod class of economic importance to agriculture is the Arachnida, which contains such animals as scorpions, spiders, mites and ticks. The scorpions and spiders are carnivorous and are thus considered to be beneficial to agriculture as they help control populations of insects that may be harmful to crop plants. Ticks and mites are however generally harmful to man's food production efforts; ticks being pests of livestock and mites attacking crop plants and stored products (although it should be noted that some mite species are predatory and others parasitic, and may thus be beneficial).

Arachnids may be distinguished from insects on the basis of several structural differences:-

- The body is divided into two regions (often difficult to see in mites).
- There are no antennae
- The mouthparts are simple and modified for rasping and biting.
- The adults possess four pairs of walking legs (mite larvae only possess three).
- There are no wings.

This structure is illustrated in Figure 6, showing the mite Tetranychus .

FIG. 6 . TETRANYCHUS TELARIUS



In considering pests of crops, the only group of Arachnids of importance is the Acari or mites. These animals are very abundant and occur in a large number of widely differing habitats; on damaged or decaying matter, on fungi, within buds or leaves, externally on leaves or stems and in stored foods such as flour. The main species of importance to food legume production in West Asia is the red spider-mite (Tetranychus urticae), which is a complex of species with a very wide host range.

#### Red-Spider-Mite

#### Importance and Occurrence

T. urticae is a highly polyphagous pest and infests a large number of different crops, including beans, alfalfa, broadbeans, tomatoes, cucumbers, tree fruits and soft fruits (strawberries etc....).

As a result of the indiscriminate use of broad spectrum insecticides many of the natural predators of the red spider mite have been severely affected and together with the levels of resistance that the pest has built up to many of the commonly used pesticides, this has caused a tremendous increase in mite populations throughout the world. So much so that mites are now very serious pests of a large number of field crops in many different environments.

#### Type of Damage

The leaves of plants infested with T. urticae turn brown as a reaction to the sucking of the mites, gradually die and are shed. Characteristic white webs are spun on the undersides of leaves and the small juvenile mites can be seen moving within these in severe infestations.

#### Identification

The mites are minute (maximum size about 0.5mm) and thus infestations are primarily identified on the basis of the white webs on the lower leaf surfaces.

Under closer examination the mite, which is sack-shaped and covered with spines, may be identified (Figure 7). The colour varies with the host from pale green to brown or orange, but two darker spots are always present near the head. The larval stage only has three pairs of legs and is generally lighter in colour, as are the four-legged other juvenile stages (nymphs).

### Life Cycle

The fertilised female mites overwinter in protected locations, usually on woody plants. In spring the mites infest weedy species before moving to crop hosts on which they usually lay their eggs. The eggs, numbering from 100 to 250, are laid on the underside of leaves within white webs spun by the females for this purpose. The eggs hatch into larvae (the first juvenile stage), which grow and pass through a resting stage into the first nymphal stage (second juvenile). The active nymphs pass through two further resting stages before emerging as adult mites. The juvenile stage (from larva to adult) takes six days at 22°C and up to 32 days at temperatures of about 10°C, and thus several generations may be produced per year. The adult mites copulate immediately upon emergence and the next generation eggs are laid two days afterwards.

### Control \*

As the overwintering adults prefer woody plants, initial infestations of this pest may be reduced by removing or treating all hedges and trees in the vicinity of susceptible crops.

Chemical control of infestations presents problems as the pest have achieved resistance to a large number of the commonly used insecticides. However several specific acaricides are now available and have been shown to give effective control.

\* See Section III

NEMATODES

The Phylum Nematoda contains a large number of microscopic soil and plant living crop parasites, the eelworms. These minute animals have long been known to attack crop plants, but because of their size and the great difficulty experienced in their extraction from soil and plants and in their identification, the nematode fauna of agricultural soils is very imperfectly understood. Thus some field symptoms previously attributed to other micro-organisms (such as viruses or bacteria) may well in fact be caused by undiscovered parasitic eelworms.

Most plant feeding nematodes live in close association with plant roots and underground structures, either as external (ecto-) parasites or internally within plants as endo-parasites. Whichever their mode of living all parasitic nematodes experience a soil phase in their life cycle and, because of their lack of inherent mobility, depend upon the characteristics of the soil for their distribution. Open textured soils and a high moisture content favour their growth and widespread movement, but very dry soil moisture conditions can cause severe dessication.

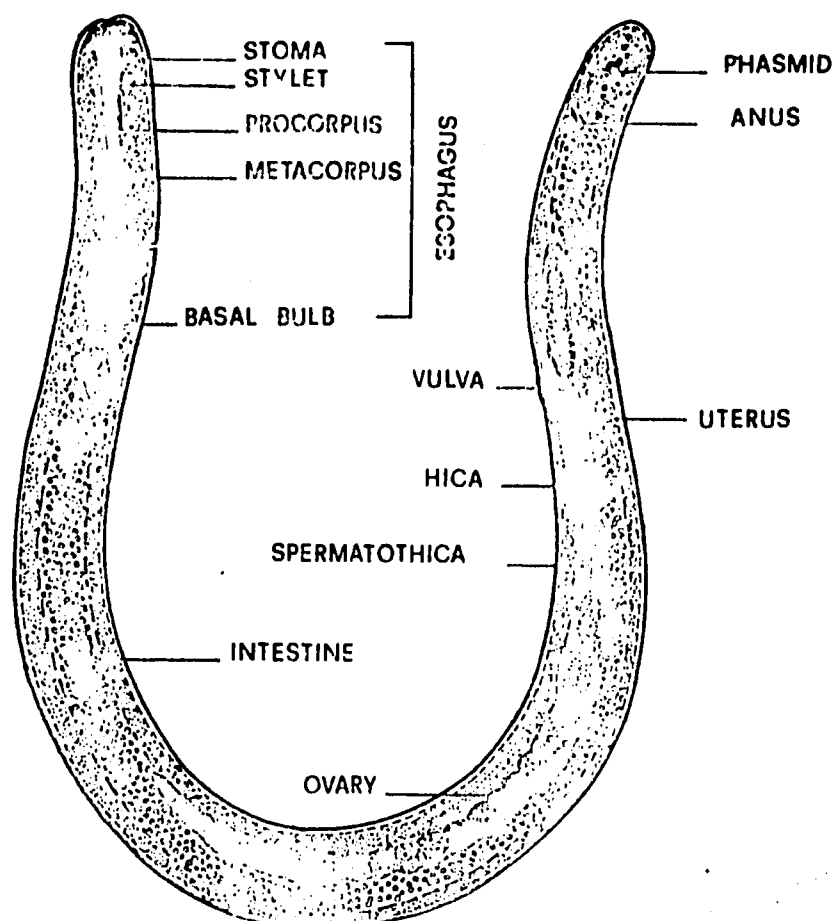
Nematodes which live in the soil surface and invade their host plants at the seedling stage being carried upwards as the plant grows or which climb plants when they are covered with water films in order to invade the aerial parts are much more susceptible to dessication from extreme environmental conditions than those deep soil living species, which can migrate further into the soil profile to escape the effects of soil drying. Thus the majority of soil surface living eelworms have developed mechanisms enabling them to withstand dessication. These also enable them to be transported over greater distances by wind, animals and man and cause wide ranging infestations.

All grades of relationship exist between eelworms and their hosts; from unspecific external parasitism (some species will parasitise a wide range of different hosts) to highly host specific internal parasitism (other species require a specific host which responds to feeding in a very specific way).

### Nematode Structure

The typical nematode structure is illustrated in Figure 7 . Basically the microscopic body consists of two tubes; the outer consisting of the 'skin' and the inner comprising the 'gut'. Between these tubes lie the reproductive organs. The mouthparts are modified for piercing and sucking and these animals feed in very much the same way as Homiptoran insects.

FIG. 7. NEMATODE ( PRATYENCHUS SP. )



### Nematode Reproduction and Growth

All eelworm reproduction is sexual; males and females being present in all species. After copulation the fertilised eggs are enclosed in a gelatinous sack which remains attached to the female. Hatching may be delayed under adverse environmental conditions (or in some species which require the stimulus of a hatching factor released by the host plant roots) and thus the pests can survive periods when either the climate is unfavourable or the host (if it is very specific) is absent. The juveniles are termed larvae although they resemble the adults closely, only do not possess mature reproductive organs.

### Plant Injury

Whatever their habitat, whether inside or outside the host plants, all nematodes feed in a similar way. The lips are pressed against the wall of a host cell and repeated thrusts are made with the spear-like mouthparts until penetration is achieved. Saliva is then injected into the cell (to assist in cellular breakdown) and the cell juices are sucked back into the animal to be fully digested. Damage to the plant hosts from this feeding is expressed in a number of ways including; the production of necrotic lesions; the stimulation of cell growth and division, causing the formation of 'giant cells' which act as feeding nectaries, and galls; general stunting of plant growth in stems, leaves and flowers; the appearance of surface lesions; and typical blotching and discolouration of plant tissue. These direct symptoms depend upon the host plant and the species of parasite and its mode of life. Indirect damage is also caused through virus transmission and by the wounds and lowered plant resistance, caused by feeding, which facilitates the entry and establishment of bacterial and fungal diseases.

### Classification

Nematodes may be classified on the basis of their structure, but as specialised equipment is necessary to resolve the minute structural differences on which this classification is based, an ecological classification (based on the type of parasitism) is often of more immediate practical use.



On this basis the nematodes can be divided into three groups: ECTOPARASITES, which feed from plant cells but which live their whole life cycle externally in the soil; SEMI-ENDOPARASITES, which normally only feed with the front part of their body embedded in the host, but can become totally internal feeders; and ENDOPARASITES, which feed totally enclosed within their hosts. Each of these groups can be further sub-divided, on consideration of their habits, into Migratory or Sedentary.

Migratory nematodes, because of their movement from host to host, are generally considered to be the most important virus vectors. Of these the Ecto-parasites are particularly important as they are highly polyphagous, fitting in well with the wide host ranges of viruses. Sedentary nematodes however tend to inflict more direct damage upon their hosts, remaining for the bulk of their life on a single plant. The majority of the economic damage caused by this group results from infestations of Endoparasitic species which, being within the host plant are better positioned to cause more disruption to it.

ECTOPARASITES

- |                    |                       |
|--------------------|-----------------------|
| - <u>Migratory</u> |                       |
| Xiphinema spp.     | Dagger nematodes      |
| Longidorus spp.    | Needle Nematodes*     |
| Trichodorus spp.   | Stubby root nematodes |
| - <u>Sedentary</u> |                       |
| Paratylenchus spp. | Pin. nematodes        |
| Crinonemoides spp. | Ring nematodes        |

SEMI-ENDOPARASITES

- |                           |                                 |
|---------------------------|---------------------------------|
| - <u>Migratory</u>        |                                 |
| Rotylenchus spp.          | Spiral nematodes*               |
| Tylenchorhynchus spp.     | Stunt nematodes*                |
| - <u>Sedentary</u>        |                                 |
| Rotylenchus reniformis    | Reniform nematode* <sup>o</sup> |
| Tylenchulus semipenetrans | Citrus nematode <sup>+</sup>    |

ENDOPARASITES

- Migratory
  - Paratylenchus spp. Lesion nematodes \*
  - Ditylenchus dipsaci Stem & bulb nematode \*
  - Aphelenchoides spp. Bud & leaf nematodes
- Sedentary
  - Anguina spp. Flower & leaf gall nematodes \*o++
- Heterodera spp. Cyst nematode
- Meloidogyne spp. Root-knot nematode \*o+ +

\* Infesting broadbeans

o Infesting chickpeas }

+ Infesting Lentils }

Few studies have been undertaken in the Middle East as yet.

Although the nematode populations of agricultural lands of western Asia are very incompletely known and very few studies have been conducted, a number of species (indicated above) have been reported attacking leguminous crops in the region. Considerable work remains to be done on both the identification of nematode pests and the assessment of the damage that they cause to these crops.

## CHAPTER 9.

### MOLLUSCS

#### Importance and Occurrence

The Phylum Mollusca contains a number of soft-bodied, unsegmented animals, many of which are marine. Some terrestrial species of importance to agriculture, namely slugs and snails, are however contained in this group. These species are, in general, not well adapted to terrestrial life under harsh conditions and, having no waterproof covering, are greatly affected by changes in the relative humidity. As a result slugs and snails are normally confined to the wetter, more humid coastal areas of the region. Even in these areas they feed only at night, when the temperature drops and the humidity rises; sheltering from the direct sunlight in the moist soil or under plant debris during the daylight hours. Both slugs and snails may cause considerable damage in garden and vegetable crops, but it is only really the slugs that are of importance to agriculture on a field scale. The overall importance and occurrence of these pests in western Asia still remains to be accurately assessed.

### Type of Damage

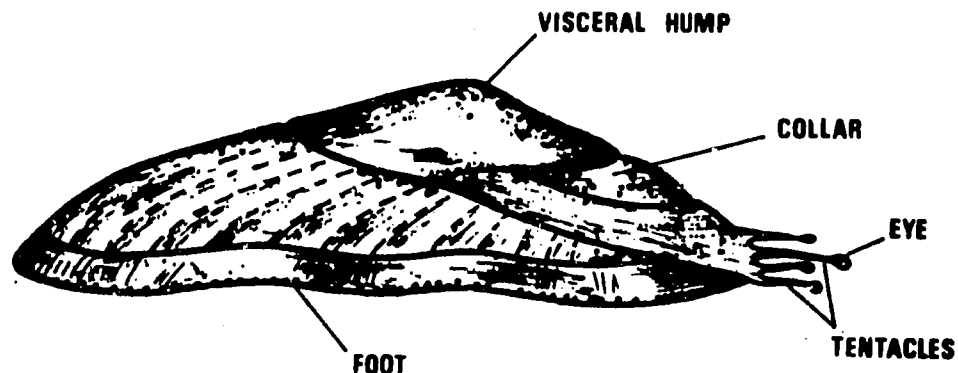
Slugs are unspecialised feeders and cause crop damage both above and below the soil surface. They have mouthparts modified for sawing and rasping and their feeding thus results in leaf shredding and or the cutting off of plants at or below ground level. In addition some types of seed may be seriously attacked following sowing.

### Identification

Slugs and snails are very easily distinguishable from insects, arachnids and nematodes on the basis of their appearance and size (Figure 8 ). Snails possess conspicuous shells, but in the slugs this structure is generally rudimentary, often internal and seldom observable.

FIG . 8 .

SLUG ( AGRIOLIMAX RETICULATUS )



### Life Cycle

Slugs and snails are hermaphrodite, possessing both male and female reproductive organs. However cross-fertilisation is usually the rule (unless populations are very low) and the eggs are laid after copulation in batches of 10-30 in damp holes in the soil, or under any suitable protection. These eggs are usually laid in the summer or autumn and can withstand freezing. Under favourable conditions they hatch after about 32 days; producing young which resemble the adults in all but size. Breeding does not take place throughout the year; being confined largely to one season. Thus there is only one generation per year .

### Control \*

Slugs and snails have a number of predators amongst the higher animal Orders (especially birds and small mammals), but these natural enemies are often unable to keep large populations in check.

These pests, due to their unspecialised feeding habits, may be caught by traps (consisting of succulent and pungent leaves), collected and destroyed. However the best control measure involves the use of poison baits, consisting of a mixture of metaldehyde and bran, beet pulp or tea leaves. The bait should be broadcast thinly or placed in small heaps on the ground in the evening when the soil is moist. It attracts slugs and snails and stimulates them to the excessive production of slime, which reduces their mobility and leads to dessication during the daylight hours providing that environmental conditions remain dry. Rainfall lessens the effect of such treatments.

\* See Section III

CHORDATES

Crop damage from small mammals and birds (sub-phylum Vertebrata) should not be ignored, as these animals are warm blooded, in contrast to the Arthropods, Nematodes and Molluscs, and their activity is thus not limited to such an extent by temperature constraints. This fact, coupled with their very great mobility, enables vertebrate pests to cause damage over a wide area throughout the year. Birds and mammals possess well developed senses and their behaviour patterns are complicated and often varied in the light of experience. They are thus considerably more difficult to deal with than the other main agricultural pest species.

Importance and Occurrence

The intensification of agriculture, with large areas devoted to similar crops and the accumulation of harvested produce in barns, has provided an abundance of easily located food for these pests.

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Together with the expansion of settlement and hence buildings, which give birds and small mammals excellent shelter during the winter months, this has led to a great increase in the importance of such pests in recent centuries.

Mammalian pests include rodents (rats, mice and mole rats), leopines (hares and rabbits) and the main species of birds classed as agricultural pests are pigeons, sparrows, starlings and rooks

The damage caused by these pests has been the subject of considerable controversy and there is presently a great need for detailed and objective studies into the behaviour, habits and populations of such species and assessments of the crop losses that they actually precipitate.

#### Type of Damage

Birds and small mammals can cause wide ranging damage to field crops and to grain in store.

Pigeons and other birds feed on young seedlings and the leaves and succulent shoots of older plants (causing severe mechanical damage through loss of leaf area and destruction of growing points) in the winter months when food is in short supply. However they have a marked preference for grains and may be particularly damaging to newly sown seeds, especially if they are inadequately covered or protected, or to developing seeds in their pods during the ripening stage. In general damage tends to be more severe in the winter months as food is scarce and the birds are concentrated onto preferred crops (such as peas and beans).

Birds may cause particularly severe damage to the flowers and developing pods of broadbean crops.

Small mammals, such as mice and mole rats, may cause severe damage to legume crops in some locations. Mice attack succulent young plants and seeds by eating the stems or digging up the seeds. Mole rats, on the other hand living entirely below the soil surface, are particularly damaging to the seeds and underground parts of the crops when present in sufficient numbers. In addition rabbits and hares can precipitate total crop losses through grazing. In common with birds, small mammals tend to cause particularly serious damage in the colder winter months.

#### Identification

Nothing really needs to be said on the identification of these pests as each has its own distinctive features by which it has traditionally been immediately recognised.

#### Life Cycle

Birds and small mammals have a number of different life cycles. Birds normally only have one generation per year; eggs being produced after copulation in the spring or early summer and hatching into young, which are fed by the parents until they attain their own independence after about 30 days. A number of broods may be reared each year by one pair of adults. The young mature finally after about 3 months and are ready to breed in the following season.

In contrast small mammals reproduce at a very rapid rate (each breeding pair of mice, for example, having about 4-10 litters of young per year) and the young mature very quickly. As they breed throughout the year under favourable conditions several generations are possible each year. Under colder winter conditions, however, a number of species (e.g. field mice and voles) go into a period of greatly reduced activity and body functions (hibernation), from which they emerge as temperatures rise in the spring. Thus in those species population expansion is less rapid.



### Control

Birds may be prevented from eating seed or damaging growing plants by a number of mechanical devices designed to frighten them away from the crops (e.g. scarecrows, revolving bird scarers and devices which imitate the explosion of a gun). There is of course no real substitute for actually shooting them, but this is very labour intensive and costly and when there are large populations not very effective, as the pests are very mobile, travel over great distances, and learn to avoid 'dangerous' areas. The practice of applying repellant or poisonous dressings to seed before planting has also proven largely ineffective in protecting newly sown seed. In fact there are no really satisfactory means for obtaining the level of kill (80-90%) now deemed desirable for the control of rabbits and rats.

Measures used to control rabbits include trapping, shooting, destroying nesting sites and erecting protective netting around particularly preferred crops in areas with high populations of the pest. The viral disease, myxomatosis has proved very effective in some countries but its cruelty is well known and where rabbits live and nest above ground it has no effect. Perhaps the most effective control involves an integration of the above mentioned measures, with the use of poison baits (now illegal in some countries).

Poison baits are however the most commonly used and effective measure for the control of rat and mice populations especially in stored products. Good rodenticides should be colourless, odourless, specific to rodents and should not induce tolerance or act so rapidly that the animal perceives warning symptoms before a lethal dose is consumed. Care should be taken in the composition and placing of the baits in order to give maximum effect as, where sub-lethal doses of many poisons are consumed over a long period, species can build up levels of resistance to these chemicals.

Although different species of mammalian and avian pests obviously occur in different areas, the groups are in general the same as outlined here and the measures used for their control will be essentially similar, although modified by tradition and location.

SECTION III

PEST CONTROL

## CHAPTER 11

### CONTROL MEASURES

Consideration of pest problems in general and the various specific pests of importance to legume production in the west Asian region in particular has served to illustrate that all pest problems are related directly to numbers; and specifically to the population density of the pest above which economic injury occurs (the economic threshold).

An understanding of the habits of individual pests and their modes of living enables us to devise measures which effectively limit their numbers to below the economic threshold and at the same time ensure a minimal disruption of the ecological balance of which these animals are a fundamental part. To achieve this form of control it is essential to understand both the concepts of economic threshold and of ecological balance.

The economic threshold, which should be used as the yardstick of control, obviously varies considerably for each crop/pest situation. It depends upon crop type and pest species, which determine the location and severity of crop injury (damage to flowers, pods and seeds tends to be more serious than similar levels of leaf damage, and rodents obviously cause more damage per individual than seed beetles in stored grain); and also upon the level of damage that the consumer will tolerate, reflected

in the price that is obtained for the produce (infestations of beetles or larvae in seed clearly affect the consumer more than infestations which only damage the growing plant and not its produce), so that while yields of seed may be adequate quantitatively the net economic return may be severely reduced from a qualitative aspect. The accurate assessment of economic pest control is essential as certain levels of pest infestation can be tolerated and it would be unnecessary and uneconomic to attempt to control such populations.

At the same time good pest control demands an appreciation of the ecological balance represented by each crop/pest interaction. For example, it is a common feature of animal populations that reproductive success increases with decreasing numbers and thus that control (which reduces population numbers) will tend to result in an increased reproductive rate. This is especially true in species with a high reproductive potential, such as insects, nematodes and rodents. Therefore, if the control of such a pest also decimates the populations of its natural predators, the rapidly increasing pest population stimulated by the control has no natural enemies to keep it in check. It may thus exceed its original level, making what could be a very expensive control measure of no use or even detrimental to the attacked crop.

When considering pest control in all its various forms, and in selecting a specific measure or combination of measures to control a particular problem, an understanding and appreciation of the level at which control is necessary and the consequence of this control upon the interacting animal and plant populations will enable an effective and longlasting reduction of pest damage to be secured.

There are a large number of ways, either direct or indirect, by which agricultural pest populations may be controlled. The art of good pest control is to be able to select the right measure or combination of measures for each given situation.

### Indirect Pest Control

Indirect control measures involve a modification of the environment in order to ensure that pest populations are unable to build up to epidemic levels. This may be achieved either by modifications to the crop-growing environment, which affect the survival of pests in the absence of their hosts at specific times and in particular places, or through changes to the crop itself, which make it a less suitable host or more able to tolerate the pest damage. By creating environments which do not favour the pests an indirect reduction effect may be achieved upon their populations or upon the crop injury that they cause.

### Cultural Control Measures

Cultural measures of pest control are designed to achieve reductions in crop injury through alterations in the crop-growing environment and may be particularly useful in reducing levels of infestation on young crops early in the season. Such infestations are often devastating.

Rotations which reduce the frequency of growing suitable host crops will in turn reduce the endemic populations of their major pests and thus early season infestations. These measures are more effective against relatively immobile pests (e.g. nematodes) or insect species that overwinter in the soil (e.g. seed beetles, podworms, pea moth, cutworms and agromyzid flies), but with the more mobile Hemipteran, Lepidopteran and Dipteran species (which include a number of the above) or species which are not highly host-specific (e.g. armyworms, podworms and cutworms) rotations control can only hope to reduce very early infestation levels.

The degree of early season infestation may also be reduced by agricultural practices which reduce the number of individuals surviving the winter resting period. Such practices include good crop hygiene and thorough cultivation. Crop hygiene mainly involves the eradication of seeds and crop volunteers and the timely removal and destruction of crop

remnants and residues, all of which provide protection for overwintering pests. Again although these measures may have little effect on the more mobile pest species during the course of the whole cropping season, they may usefully serve to postpone the onset of severe early infestations of pests which overwinter in this way, (e.g. nematodes, army worms, seed beetles, spider-mites and agromyzid flies).

Repeated shallow cultivations and deep ploughings during the autumn and winter months are also effective ways of reducing overwintering pest populations; ploughing, by burying insect pupae and nematodes far beneath the soil surface so that they are unable to emerge (in the former case) or reach their hosts (in the latter); and cultivations by exposing nematodes and overwintering insect larvae to dessication (from the extreme environmental conditions) or predation (by birds and small mammals) at the soil surface. Insect pests which overwinter in the soil surface layers either as larvae (e.g. armyworms, pea moth and cutworms) or as pupae (e.g. armyworms, cutworms and agromyzid flies) are affected by such practices.

Of more widespread application is the well-known practice of early sowing using early maturing and cold tolerant varieties (if necessary) so that the crop is past its more susceptible young stage by the time that the pests are abundant enough to cause severe infestations. Such 'avoidance' measures, because they are not specific to certain individual pests, but to all cold-blooded animals (which do not become active until the warmer spring temperatures permit) have a much broader spectrum of control and can be successfully used to reduce damage caused by nearly all Arthropod, Mollusc and Nematode pests.

Used in isolation, individual cultural control measures generally produce only marginal benefits. However they are often less costly (although more labour intensive) than other forms of control, and when used in an intelligent combination (based on the habits and life cycle of the pests to be controlled) and on a regular annual basis cultural controls can lead to steadily declining populations and consequent reductions in crop losses.

### Host Defence Mechanisms

Over the course of their long evolution in close contact with pest species plants have developed a number of mechanisms which limit the destructive effects of these animals to a greater or lesser extent. Three distinctly different mechanisms can be recognised, namely: preference, resistance and tolerance.

Preference arises when a variety is not preferred by a pest for egg-laying or for feeding, either through a failure to attract the pest or by an active repulsion. In a pure form preference is evident between plant species in a pest's choice of host. Analysis of the factors which govern the host ranges of specific pests may yield valuable information on the plant characters which determine them and which might thus be introduced into a crop to protect it from the pest. There is considerable risk of preference being mistaken for a high level of resistance in field observations. It should be remembered in this regard, that there is nothing to prevent a pest attacking a non-preferred type, apart that is from its own preference. As a result the widespread use of varieties based on preference may lead to disastrous losses, as the pest has no choice but to infest the crop even though it is not preferred.

In contrast host defense mechanisms conferring resistance to a pest or pests constitute a much more positive way of reducing infestations. Resistance can be : mechanical, such as tissue resistant to biting or piercing, which manifests itself as pest restlessness and possibly also a lengthened life cycle and decreased fertility : or physiological, involving the deactivation of enzymes or poisons contained in the saliva of sucking insects, the production of factors toxic to specific pests, or incompatible responses to feeding (with certain very specific pests).



Mechanical resistance is in general more broadly based, effective against a large number of different insects with the same mode of living, and thus is more stable against a wide range of individuals. In contrast physiological resistance is usually rather specific to particular pests.

These defense mechanisms may be introduced into well-adapted production varieties through plant breeding as a way of reducing pest infestations. Such varieties constitute a very good method of control, but plant breeders must beware of introducing varieties with resistance based on the more specific mechanisms outlined above. This is because the use of such varieties exerts a considerable selection pressure on the pest population (which like all populations is composed of individuals, all with differing characters). Soon all the forms unable to overcome this resistance barrier will be almost eliminated, leaving those individuals still able to infest and damage the crop a clear advantage to expand and dominate the pest population. In this way varieties with resistance based only upon highly specific defense mechanisms may 'become susceptible' very rapidly. A continual development of new resistant varieties will thus be necessary. The use of a combination of mechanical and physiological resistance mechanisms in crop varieties should thus be viewed as more important in achieving a high degree of resistance of long-lasting effectiveness.

The third way in which the destructive effects of crop pests may be minimised is through crop tolerance. Tolerance basically involves the ability of certain types to grow rapidly and more vigorously if infested and thus to replace plant parts that are damaged. Conditions which promote healthy plant growth and reduce stress resulting from severe environmental effects will considerably assist the expression of tolerance.

It is thus important to ensure that agronomic conditions are kept as favourable as possible if this effect is to be exploited.

While pest control through the enhancement of host defense mechanisms is perhaps the most complete and lasting way of minimising pest damage, the achievement of strong and broad-based defenses is a very long term objective and as a practical control measure should be seen as having limited applicability at present.

#### Direct Pest Control

Direct control measures are designed to give immediate and often dramatic reductions in pest populations, in contrast to indirect measures which, if used correctly, lead to a steady decline in populations over a longer time period. They are, in general, considered to be 'short-term' measures which, although they have a great initial impact upon pest populations, have to be repeated regularly to achieve continuing control. While the long-term population decline achieved by indirect control is an obvious aim, such measures are largely ineffective in combating field infestations that require immediate and effective control. In these situations direct control is the only alternative to serious crop losses.

Direct reductions in pest populations may be achieved by measures aimed at the destruction of individuals or a disruption of their reproductive abilities. A number of different mechanisms are available in this regard.

#### Control through Reproductive Disruption

Rendering an animal sterile is often a more effective way of controlling its species than actually killing it. This is primarily because the sterile

animal (providing of course that sterility does not affect its mating behaviour) remains to compete with normal individuals for mating partners (producing non-viable off-spring), thereby preventing the rapid increase in breeding success of resistant individuals which normally results from control based upon removal of individuals.

A number of methods, based on this premise, have been evolved to combat agricultural pests. However the procedures presently necessary to produce sterility (usually involving irradiation in some form) are far too costly for control to be economic on a farm basis. The development of chemicals of the hormone type able to produce the same effects when applied as a bait or spray might serve to make this doubtlessly effective control mechanism economic for a wider range of producers.

### Biological Control

In nature the ecological balance of animal species is maintained through a series of interactions (A eats B and is eaten by C etc. ...). It follows that all animal species have their natural enemies. Agricultural pests are no exception, falling victim to predators, parasites, fungi, protozoa, bacteria and viruses.

Biological control aims to make use of this situation, by the artificial increase and release of such enemies, which then cause the destruction of the pests. In this way a direct reduction in pest populations may be achieved by a manipulation of the environment. This may cause less drastic ecological disruptions than the addition of some alien matter (e.g. chemicals). However when pest populations are small these natural enemies may not be very effective, only making an impact on large populations. If this is the case then control will only be exerted after the populations have built up and some crop damage has already been caused.

In most cases the process of bulking up the natural enemy is very costly and relatively time consuming. So, in spite of such notable success as

the control of citrus mealy bugs with ladybird predators and myxomatosis virus, biological control at present has a rather limited application. Current emphasis is on the development of micro-organisms applied through sprays as a type of 'living insecticide' at this present position.

### Chemical Control

Perhaps the best known and most widely used method of pest destruction involves the use of toxic chemicals. Considerable research in recent years has resulted in the development of a wide range of such chemicals known as pesticides) whose cost effectiveness is second to none. However when considering the use of pesticides as a method of pest control, the effects of a particular chemical upon the environment (the pest's natural enemies and its persistence in a toxic form) must be carefully balanced against its effectiveness against the pest. This is especially necessary as living processes in plants and animals are in common and are thus likely to suffer the toxic effects of chemicals in similar ways. Thus, with the exception of a few very highly specific chemicals, most pesticides are 'broad-band' toxicants, that is, they have the potential to damage all living things. Any selectivity that is observed therefore tends to result from the way in which they are used rather than from their inherent properties, making it of tantamount importance to ensure that they are applied in the right way, at the right concentration, at the correct time and in the correct place. If used without regard to these factors, the effectiveness of pesticides may be completely lost and very serious damage may be caused to the crop and indeed to the whole environment.

Providing that the danger of toxic chemicals is appreciated and a wide range of environmental considerations taken into account in selecting specific chemicals for particular jobs and due care exercised in their use, pesticides are a valuable tool in pest control.

Pesticides are commonly classified according to the type of pest against which they are used; thus insecticides are used against insects, acaricides against mites, molluscicides against slugs and snails, nematocides against nematodes and rodenticides against rodents.

### Insecticides \*

Just as insects are the most important group of agricultural pests, so insecticides are the largest and most researched group of pest control chemicals. They can be sub-divided according to their mode of action into a number of classes:-

Contact Poisons: which gain entry to the insect through the outer skin. These chemicals are thus only effective against exposed feeders and tend to have rather a broad spectrum of activity (killing pest and predator alike). However their persistence is generally low as they are inactivated fairly rapidly by the effects of the environment and they are therefore only used as curative chemicals (when infestations are observed). Due to their general lack of persistence and mode of action, a number of contact poisons (e.g. Nicotine, Rotanone and Pyrethrum - Plant Derivatives) must be applied repeatedly and in large volumes to give a good crop cover. Notable exceptions however are the organo-chlorine chemicals (e.g. DDT, TDE, Methoxychlor, gamma-BHC, Aldrin, Dieldrin and Endrin) which are both powerful and persistent contact poisons. Because of these properties organo-chlorine compounds may be used in a protective role (before infestations are observed) and the timing of their applications is not critical.

Fumigants: which gain entry through the breathing mechanisms of pests (tubes culminating at the skin surface in the case of insects). These chemicals are diffused in the air and thus must be used in enclosed spaces

\* See Tables 1, 2, 3 and 4.

in order to be effective. They find use against pests of stored grain and soil living micro-organisms but as treated soil must be surfaced sealed they thus have little utility under field conditions. Examples of chemicals used as fumigants include: nicotine, methyl-bromide, chloropicrin, carbon disulphide, ethylene oxide and hydrocyanic acid gas.

Stomach Poisons: which gain entry through the pest stomach and thus must be ingested before becoming effective. Although possessing high mammalian and plant toxicity, some stomach poisons (e.g. arsenic compounds) may be given some selectivity by application in the less toxic, insoluble form; only becoming toxic upon ingestion, when rendered soluble by the stomach acids. The mercury compounds (e.g. calomel and mercurous chloride), with their stomach action, are commonly used to protect seeds or seedlings against concealed underground feeders, which are not affected by contact chemicals. The carbamates (e.g. Carbaryl) and the organo-chloride compounds also have stomach action when ingested and, in common with the other stomach poisons, have considerable persistence, enabling them to be used in a protective role. Stomach poisons are especially effective on pests which are voracious feeders.

Systemic Poisons: which are stomach poisons translocated within plants and ingested by pests during feeding. These poisons are particularly useful in controlling pests which feed in concealment above the soil surface and which cannot thus be affected by contact or non-systemic stomach poisons. Being translocated within the plant these chemicals can be applied in relatively small doses upon the leaves or roots to give the plant a high and persistent toxicity to pest feeders. Organo-phosphorus compounds are the most effective systemic poisons and also possess good contact activity. Examples include: Mevinphos, Parathion, Malathion, Schradan, Dimethoate, Azinphos-methyl, Phorate and Disulfoton. Some carbamate compounds (e.g. Carbaryl) also have limited systemic activity.

### Acaricides \*

In common with aphids, mites possess sucking mouthparts. They are thus susceptible to many of the systemic insecticides of the organo-phosphorus group. Some chemicals (e.g. Ethion, Chlorbenside, Chlorfenson, Dicofol and Tertradifon) are mainly acaricidal and are thus more selective than others.

### Molluscicides +

A number of carbamate compounds have molluscicidal properties, but in general the dosage required for an effective kill is too high. Metaldehyde still remains the most effective chemical for inclusion into poison baits but leaves much to be desired.

### Nematicides °

Very few effective and economic nematicides are available due to the great problems involved in getting any toxic chemical into contact with organisms so widely dispersed in large masses of soil. Fumigation is still the only effective control method, but as this involves the sealing of soil surfaces after chemical application, it is rarely of use on anything but a very small scale.

### Pesticide Formulation

Toxic chemicals are rarely (with the exception of some fumigants) applied in their pure form. It is usual to mix the pesticide with a suitable diluent in order to enable it to be more evenly and thinly spread. Common diluents include inert dusts, oils, water and air, and are chosen on the basis of the chemical to be applied and the prevailing environment.

\* See Tables 1 and 2.

+ See Table 5

° See tables 3 and 4.

Dusts for example are used for foliage and soil application and as seed dressings. Chemicals are normally field applied as dusts when they must be kept in an insoluble form, and the control of pests in stored grain demands dry applications (dusts or fumigants) to prevent spoilage

Chemicals are usually applied in the field as sprays, where the pesticide is diluted or dissolved in water or oil depending upon its properties. Contact and stomach poisons are normally applied in relatively dilute solutions (using a high volume of diluent) in order to obtain good crop coverage. Such applications can be given improved persistence by the addition of 'sticking agents' which prevent them from being washed from the leaf surface as rapidly as is normal in heavy rains. Systemic pesticides, however, do not require such a good coverage of the plants and so are usually applied in low volumes of the diluent. Granular applications are particularly useful for chemicals that are too toxic to be used as sprays and some highly volatile fumigant chemicals are often applied as granules, as are chemicals designed to kill soil living pests.

### Problems of Pesticides

Repeated use of similar pesticides has been shown to favour the selection of individuals within the pest population showing varying degrees of resistance to the chemicals. Care must thus be taken in the choice of chemicals to prevent such situations arising.

Pesticides with a high degree of persistence (e.g. arsenicals, organo-chlorine and organo-phosphorus compounds), which is favourable when considering the chemicals' effect on pests, may accumulate in crops, animal predators and the soil. This accumulation, which can be especially severe over a number of years has been found to lead to highly undesirable ecological effects, not to mention flavours and taints in harvested produce. These problems should be taken into account when selecting chemicals on the basis of their persistence.

It should be remembered that all pesticides are also toxic to man. Great care is thus necessary to ensure the safety of operators involved in their use.



### Integrated Pest Control

Direct control measures are highly effective in the short-term and can be very useful in controlling epidemic level infestations and preventing undue crop losses. However a lasting control can only be achieved by repeated and regular applications of these measures. Such practices are both costly (in terms of chemicals and time), can cause appreciable crop damage (by trampling or crushing by machinery); and are moreover dangerous in stimulating resistant forms to become dominant and in causing repeated ecological disruption (decimation of natural enemies and accumulation of residues in the crops and soil).

Indirect control measures have few of these disadvantages, but are ineffective in combating infestations in the short-term.

Logic thus suggests that the best and most effective control of agricultural pests may be achieved, both in the short term and in the long term and without undue ecological damage, through an integration of direct and indirect measures. For example chemical and cultural measures may be modified so that they work to the advantage rather than against the natural enemies of pest species. Such measures must be developed from a good understanding of both the habits and the life cycles of both the pests and their enemies. In such a way chemicals can be developed and applied so that their effect is severe on the pest populations but the populations of their enemies remain relatively untouched. This selectivity may, to a certain extent, be achieved through reducing the dosage of pesticides and applying them in the most effective manner (in seed dressings, granules or baits). However where chemical control of a pest can only be achieved by using powerful and persistent pesticides, the development and use of resistant varieties would be particularly important. In addition the

populations of natural enemies might be artificially enhanced, thus incorporating elements of biological control into the overall scheme.

A policy of integrated control, however it is practised, should result in steadily declining pest population levels, against which isolated sudden increases in specific pests (caused by migration from adjoining less well controlled areas) may be quickly and efficiently controlled by direct means which do not interfere with the delicate balance of nature preserved by indirect control measures.

Table 1.

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Some Common Organophosphorus Pesticides

No.	Pesticide Classification	Common name	Trade name	Action	Selectivity	Form	Main application	Remarks
1.	Insecticide Acaricide	Azinphos-methyl	Gusathion Guthion	Stomach Contact	None	Sprays Dusts	Mites, aphids, thrips, leaf weevils, pod borers, army worms, pea moth.	Harmful to bees
2.	Insecticide Acaricide	Bromophos	Nexion Brofene	Contact Stomach	In use	Sprays Dusts Granules Aerosols	Aphids, thrips	Not toxic to bees
3.	Insecticide Acaricide	Diazinon	Basudin Nucidol Sarolex	Contact Stomach	None	Sprays Dusts Granules Seed dressing Aerosols	Mites, aphids, leaf weevils, thrips, soil insects, cut-worms, pod borers, leaf hoppers.	Toxic to bees
4.	Insecticide Acaricide	Dichlorvos	DDVP Nogos Nuvan Vapona	Fumigant Stomach Contact	In use	Sprays Granules Aerosols Baits	Aphids, leaf hoppers, pea moth, leaf miners, seed weevils, mites, pod borers.	Toxic to bees
5.	Insecticide Acaricide	Dimethoate	Roxion Rogor Fosfamid	Systemic Stomach	None	Sprays Dusts Granules	Thrips, mites, leaf miners, leaf hoppers, aphids.	Toxic to bees
6.	Insecticide Acaricide	Disulfoton	Di-synton Sulvirex Thiodemeton	Systemic	Some	Sprays Granules	Aphids, leaf miners, leaf hoppers, thrips, mites.	Toxic to bees
7.	Insecticide	Fenitrothion	Folithion Novanol Cyfen	Contact Stomach	None	Sprays Dusts Granules	Leaf weevils, aphids, thrips, pea moth, pod borers, armyworms, leaf hoppers, stem borers, cutworms, mites	Harmful to bees
8.	Insecticide Acaricide	Fenthion	Lebaycid Baytex Baycid	Contact Stomach	In use	Sprays Dusts Granules	Leaf weevils, leaf hoppers, pea moth, thrips, pod borers, aphids, mites, army worms, leaf miners, soil insects.	Toxic to bees
9.	Insecticide Acaricide	Formothion	Anthio Afflix	Contact Systemic	Some	Sprays	Aphids, mites, thrips, leaf miners.	Toxic to bees
10.	Insecticide Acaricide	Malathion	Emmatos Malmed Malaphos	Contact Stomach	None	Sprays Dusts Granules Aerosols Baits	Aphids, mites, leaf hoppers, leaf miners, thrips, seed weevils, pod borers, leaf weevils, army worms, stored seed pests.	Toxic to bees
11.	Aphicide	Monasone	Sayfos Saphizon Saphicol	Systemic	Some	Sprays Seed Dressing	Aphids.	

Table 1. Contil,...

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No.	Pesticide Classification	Common name	Trade name	Action	Selec- tivity	Form	Main application	Remarks
12.	Insecticide Acaricide	Methamidophos	Tamaron Monitor	Systemic Stomach Contact	None	Sprays Granules	Aphids, leaf miners, leaf hoppers, thrips, mites, army worms, cut worms, pod borers.	Toxic to bees
13.	Insecticide Acaricide	Methidathion	Supracid Ultracid	Contact Stomach	None	Sprays	Pea moth, leaf miners, leaf hoppers, aphids, thrips, leaf weevils, mites, pod borers.	Toxic to bees
14.	Insecticide Acaricide	Mevinphos	Phosdrin Gastid Phosfene	Systemic Contact	Some	Sprays Aerosols	Aphids, leaf weevils mites, thrips, leaf miners, cut worms, army worms, pod borers.	Toxic to
15.	Insecticide Acaricide	Monocrotophos	Nuvacron Azodrin Monocron	Systemic Contact	None	Sprays	Aphids, pod borers, cut worms, thrips, leaf hoppers, mites, leaf miners, army worms.	
16.	Insecticide Acaricide	Oxydemeton-methyl	Metasystox-R Metasystemox	Systemic Contact	Some	Sprays	Mites, aphids, leaf hoppers, thrips.	Harmful to bees
17.	Insecticide Acaricide	Parathion	Folidol Nitrox	Contact Stomach	None	Sprays Dusts Granules Aerosols	Aphids, leaf miners, thrips, leaf hoppers, mites, cut worms, army worms.	Toxic to bees
18.	Insecticide Acaricide	Phorate	Thimet Rampart Timet	Contact Systemic Fumigant	In use	Sprays Granules	Aphid, mites, thrips leaf hoppers, leaf miners, cut worms, foliar nematodes.	
19.	Insecticide	Phosphamidon	Famfos Dimecron	Systemic Stomach	None	Sprays	Aphids, leaf miners, leaf weevils, leaf hoppers, pod borers, mites.	
20.	Insecticide	Phosphoromethyl	Actillic Blex Silosan	Contact	In use	Sprays Dusts Aerosols Seed dressing	Pests of stored products.	
21.	Insecticide Acaricide	Shradan	OMPA Pentox Sytam	Systemic	Selec- tive	Sprays	Aphids, mites.	
22.	Insecticide	Tetrachlorvinphos	Gardona Rabon Appax	Contact Stomach	In use	Sprays Dusts Granules	Cut worms, pod borers, pea moth, leaf weevils, pests of stored products	
23.	Insecticide Acaricide	Thiomethon	Ekatin Morpho- thion	Systemic	Some	Sprays	Aphids, mites, thrips, leaf hoppers.	Low bee toxicity
24.	Insecticide	Trichlorfon	Dipterex Proxol Tugon	Contact Stomach Fumigant	In use	Sprays Dusts Granules	Leaf miners, leaf hoppers, leaf weevils, cut worms, army worms.	Toxic to bees.

Table 2.

Some Common Organochlorine Pesticides

No.	Pesticide Classification	Common name	Trade name	Action	Selec- tivity	Form	Main application	Remarks
1 .	Insecticide	DDT	Anofex Arkotine Didimac	Contact Stomach	None	Sprays Dusts Granules Aerosols Seed dressing	Leaf miners, leaf weevils, leaf hoppers, pod borers, thrips, pests of stored products.	Highly toxic to bees
2 .	Insecticide Acaricide	Endosulfan	Cyclodan Thiodan Malix	Contact Stomach	In use	Sprays Dusts Granules	Aphids, beetles, pod borers, leaf hoppers, stem borers, army worms, mites.	Relatively non-toxic to bees.
3 .	Insecticide	Gamma-BHC (Lindan)	Gamaphex Gammalin Forlin	Stomach Fumigant Contact	None	Dusts Aerosols Seed dressing Smoke generator	Aphids, thrips, an's, leaf miners, army worms.	
4 .	Insecticide	Aldrin (HHDN)	Aldrex Aldrite Seedrin	Contact Stomach Fumigant		Sprays Dusts Granules seed dressing	Cut worms, army worms, leaf miners, thrips, soil insects.	
5 .	Acaricide	Bromop- roylate	Acarol Neoron	Contact	Selec- tive	Sprays	Most species of mites.	
6 .	Acaricide	Dicofol	Acarin Kelthane Carbax	Contact	Selec- tive	Sprays Dusts	Mites	Does not harm bene- ficial insects.
7 .	Acaricide	Tetradifon	Duphar Tedion	Contact	Selec- tive	Sprays	Tetradifon is effective on all forms of mites except adults.	

Table 3

Some Common Carbamate Pesticides

No.	Pesticide Classification	Common name	Trade name	Action	Selec- tivity	Form	Main application	Remarks
1 .	Insecticide	Carbaryl (Sevin)	Dicarbam Denapon Hexavin	Contact Stomach	In use	Sprays Dusts Granules Baits	Aphids, leaf hoppers, thrips, army worms, pod borers, pests of stored products.	Highly toxic to bees
2 .	Insecticide Nematocide	Carbofuran	Curaterr	Systemic	In use	Sprays Granules	Thrips, aphids, leaf weevils, soil insects, nematodes.	Toxic to bees
3 .	Insecticide Nematocide	Methomyl	Lannate Nudrin	Systemic	In use	Sprays Dusts Granules	Aphids, leaf weevils, leaf hoppers, army worms, pod borers.	Toxic to bees
4 .	Insecticide	Pirimicarb	Pirimor Aphox Fernos	Contact Fumigant	Selec- tive	Sprays Aerosols	Aphids	Low bee toxicity

Table 4.

Some Common Fumigants

No.	Pesticide Classification	Common name	Trade name	Action	Selec-tivity	Form	Main application	Remarks
1.	Insecticide Nematicide Rodenticide	Carbon Disulfide	Carbon Bisulfide	Fumigant	None	Liquid	Nematodes, rats and mice, pests of stored products.	Danger
2.	Insecticide Nematicide Rodenticide	Methyl Bromide	Profume	Fumigant	None	Gas	Nematodes, soil insects, pests of stored products, rats and mice.	Danger
3.	Insecticide	Phosphine	Celphos Delicia Phostoxin	Fumigant		Pellets Tablets	Pests of stored products in silos	Danger

Table 5.

Some Common Molluscicides

No	Pesticide Classification	Common name	Trade name	Action	Selec-tivity	Form	Main application	Remarks
1.	Molluscicide	Metaaldehyde	Antimilace Namekil			Baits	Snails, slugs	
2.	Molluscicide Insecticide Repellent	Methio-carb	Draxa			Sprays Dusts Baits	Insects, mites slugs, snails, bird repellent	Highly toxic to bees.

Table 6.

Some Common Rodenticides

No	Pesticide Classification	Common name	Trade name	Action	Selec-tivity	Form	Main application	Remarks
1.	Rodenticide	Zinc phosphide	Phosium	Stomach	in use	Baits Powders	Mice, rats	
2.	Rodenticide	Chlorophacinone	Rozol Toptox	Anti-coagulant	in use	Powders	Mice, rats, moles.	Low toxicity to birds.
3.	Rodenticide	Coumatetralyl	Racumin Endox Endrocid	Anti-coagulant		Powders Baits Liquids	Mice, rats.	
4.	Rodenticide	Couma-chlor	Tomoron Ratilan	Anti-coagulant		Baits	Mice, rats	
5.	Rodenticide	Coumar-furyl	Fumarin Fatafin Tomarin	Anti-coagulant		Baits	Mice, rats.	

Table 7 : SOME IMPORTANT INSECT PESTS REPORTED ON LEGUMINOSAE IN WEST ASIA.

Order	Sub-Order	Super-Family	Family	Genus	Species	Common Name	Host(s)
Othoptera	Ensifera	Grylloidea	Gryllotalpidae	Gryllotalpa	gryllotalpa	Mole cricket	Most legumes.
Hemiptera	Homoptera	Aphidoidea	Aphididae	Aphis = Uroleis	fabae	Bean aphid	Broadbeanbushbean
Hemiptera	Homoptera	Aphidoidea	Aphididae	Aphis	craccivora	Black aphid	Most legumes.
Hemiptera	Homoptera	Aphidoidea	Aphididae	Acyrtosiphon	= laburni	Pea aphid	Peas, vetch, sweet clover
Hemiptera	Homoptera	Aphidoidea	Aphididae	Macrosiphum	= pisum	Clover aphid	Bur clover, Berseem, Crimson clover.
Hemiptera	Homoptera	Cicadelloidea	Cicadellidae	Therioaphis	trifolii	Leaf hopper	Most legumes.
Coleoptera	Polyphaga	Chrysomeloidea	Bruchidae	Empoasca	lybica	Bean beetle	Broad beans.
Coleoptera	Polyphaga	Chrysomeloidea	Bruchidae	Bruchus	rufimanus	Pea beetle	Peas.
Coleoptera	Polyphaga	Chrysomeloidea	Bruchidae	= Mylabris	pisorum	Dried bean beetle	Dried bean
Coleoptera	Polyphaga	Chrysomeloidea	Bruchidae	Acanthoscelides	obtectus	Cowpea beetle	Cowpea.
Coleoptera	Polyphaga	Chrysomeloidea	Bruchidae	= Bruchidius	maculatus	Lentil beetle	Lentils
Coleoptera	Polyphaga	Curculionidae	Curculionidae	Callosobruchus	= quadrimaculatus	Pea and bean weevil	Pea, bean, clover, lucern.
Coleoptera	Polyphaga	Curculionidae	Curculionidae	= Bruchus	annalis	alfalfa weevil	Alfalfa
Coleoptera	Polyphaga	Curculionidae	Curculionidae	Bruchus	lineata	Seed weevil	Broadbeans, lentils.
Coleoptera	Polyphaga	Curculionidae	Curculionidae	Sitona	variabilis		
Coleoptera	Polyphaga	Curculionidae	Curculionidae	Phytonomus	= postica		
Coleoptera	Polyphaga	Curculionidae	Curculionidae	= Hypera	arrogans		
Coleoptera	Polyphaga	Curculionidae	Curculionidae	Apion			
Lepidoptera	Ditrysia	Papilionoidea	Lycaenidae	Lycaena	baetica	Bean butterfly	Bean, pea, cowpea, betch.
Lepidoptera	Ditrysia	Noctuoidea	Noctuidae	Laphygma	exigua	Army worm	All legumes
Lepidoptera	Ditrysia	Noctuoidea	Noctuidae	= Spodoptera	litura	Cotton leaf worm	Alfalfa
Lepidoptera	Ditrysia	Gelechioidea	Gelechiidae	Prodenia	alfalfella	Lesser alfalfa moth	Alfalfa
Lepidoptera	Ditrysia	Noctuoidea	Noctuidae	Aproaerema	ypsilon	Greasy cutworm	All legumes
Lepidoptera	Ditrysia	Noctuoidea	Noctuidae	Agrotis	armigera	Pod borer	Chickpea
Lepidoptera	Ditrysia	Noctuoidea	Noctuidae	Heliopsis	= obsoleta	Pea moth	Peas
Lepidoptera	Ditrysia	Tortricoidea	Olethreutidae	Laspeyresia	nigricana		
Diptera	Brachycera	Opomyzoidea	Agromyzidae	Melanaqromyza	phaseoli	Bean fly	Beans
Diptera	Brachycera	Opomyzoidea	Agromyzidae	= Agromyza		Pea fly	Peas
Diptera	Brachycera	Opomyzoidea	Agromyzidae	Phytomyza	atricornis	Broadbean fly	Broadbean
Diptera	Brachycera	Opomyzoidea	Agromyzidae	Liriomyza	= horticola	Chickpea fly	Chickpea
Diptera	Brachycera	Opomyzoidea	Agromyzidae	Liriomyza	trifolii	Alfalfa fly	Alfalfa
Diptera	Brachycera	Opomyzoidea	Agromyzidae	Liriomyza	congesta		
Diptera	Brachycera	Opomyzoidea	Agromyzidae	Agromyza	nana		